AMERICAN SOCIETY
OF
SUGAR BEET TECHNOLOGISTS

PROCEEDINGS OF THE THIRD
GENERAL MEETING

Part I (pp. 1 - 157)

Contents
Officers and Committees
Active and Associate members attending
Banquet
General Session
Section A - General Agronomy, Soils, Fertilizers, Production and By-Products
Section B - Genetics, Breeding, Seed and Varieties

DENVER, COLORADO

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Active and Associate members attending Third General Meeting

Banquet

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*Riddell, W. H.	Great Western Sugar Co.	Fort Collins, Colo.
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B A N Q U E T

January 5, 1940

Program

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WELCOME - - - - - - - - - - - - - Mayor Benjamin F. Stapleton

OBSERVATIONS- - - - - - - - - - Governor Ralph L. Carr

THE SUGAR INDUSTRY AND
RESEARCH - - - - - - - - - Frank A. Kemp

ENTERTAINMENT - Courtesy of The American Crystal Sugar Company and The Great Western Sugar Company

General Session - Chairman: W. W. Robbins

SOME ILLUSTRATIONS OF METHODS IN PLANT BREEDING[1]

H. K. Hayes
Division of Agronomy and Plant Genetics, University of Minnesota

While most important food plants had already been brought under cultivation before "the dawn of recorded history," as emphasized by several writers, there is, at present, almost an unlimited opportunity to improve the varieties of plants available for various agricultural uses and in some cases to greatly modify their characters. The primary purpose in plant breeding is to obtain or produce varieties or hybrids that are efficient in their use of plant nutrients, that give the greatest return of high quality products per acre or unit area in relation to cost and ease of production and that are adapted to the needs of the grower and consumer. It is also of extreme importance to obtain varieties that are able to withstand extreme conditions because of resistance to pathogenic diseases or insect pests, or that excel in drought or cold resistance. Such qualities help materially to stabilize yields by a partial control of seasonal variations in yield.

Muller (14)[2], early leader in studies of induced mutation, discussed the importance of gene knowledge and control with respect to plant improvement, making the following statement which I quote:

> "Organisms are found to be far more plastic in their hereditary basis than has been believed, and we may confidently look forward to a future in which - if synthetic chemistry shall not have displaced agriculture - the surface of the earth will be overlaid with luxuriant crops, at once easy to raise and to gather, resistant to natural enemies and climate, and readily useful in all their parts."

An appreciation is now available to the public, of the many problems involved in breeding improved varieties of economic plants in United States and some of the accomplishments, from summaries in the Yearbooks (17) of the U. S. Department of Agriculture for 1936 and 1937. A brief statement by Henry A. Wallace, Secretary of Agriculture, who is well known for his own studies of breeding with corn and swine, seems of particular interest. This is quoted as follows:

> "The science of the quality of life as it passes from generation to generation is in many respects the greatest and youngest of all the sciences. While the art of plant and animal breeding is an old one, the science of plant and animal genetics dates only to 1900. So far as known, this Yearbook is the first comprehensive effort to survey superior germ-plasm in the leading plants and animals. The Yearbook shows how much we know and how much more we should know but do not as

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[1]A paper presented at the meeting of the American Society of Sugar Beet Technologists, Denver, Colorado, January 4, 1940. A contribution from the Division of Agronomy and Plant Genetics in the Minnesota Agricultural Experiment Station. Published as Journal Series Paper No. 1781.

[2]Numbers in parenthesis refer to "Literature Cited," p. 16-17.

yet. True, the science of genetics is still young and growing. I trust that the day will come when humanity will take as great an interest in the creation of superior forms of life as it has taken in past years in the perfection of superior forms of machinery. In the long run superior life forms may prove to have a greater profit for mankind than machinery."

Standardization of Breeding Methods

While new technics in plant breeding are being developed from year to year, certain standardized methods have been developed for particular categories of crop plants and for specialized problems. These can be illustrated best, I think, in relation to their application.

There is a close relation between methods of breeding and normal mode of pollination. Four subdivisions are of major importance altho there is no sharp division between classes.

1. Naturally self pollinated (4% or less of cross pollination), Barley, wheat, oats, tobacco, potatoes, flax, rice, peas, beans, soybeans, cowpeas.

2. Often cross pollinated (self pollination > cross poll.) Cotton, sorghums, some strains of sweet clover.

3. Naturally cross pollinated.
   Maize, rye, clovers, sugar beets, cucurbits, most perennial grasses.
   Self sterile plants.

4. Dioecious. Hops, hemp, spinach, asparagus.

With this classification as a background it seems logical to outline some standardized methods of breeding for particular problems in relation to the biology of the plant and the type of improvement sought. Many changes of viewpoint have taken place during the 30 years that I have been actively engaged in studies of genetics and plant breeding. Early in this period it was often stated that plant breeding was largely an art. While recognizing the importance of the art I shall try to emphasize the value of a knowledge of genetics in its application to problems of crop improvement. About 1915, Dr. Raymond Pearl stated that the breeder of the self-pollinated group of plants used Mendel's Laws as a direct and working guide. In so doing the first standardized breeding program came to be designated as "the pedigree method." It consists of making a cross between parent lines that differ in several important characters followed by selection, during the segregating generations, for the combination of characters desired. Many of the characters of selection value will be related to yielding ability. There will be other genetic factors for yielding ability that can be selected by the breeder only through field trials of sufficient numbers, under proper methods of experimental design, so that the higher yielding strains can be selected on the basis of their performance.

Crossing Followed by Selection During Segregating Generations

The breeding program can be summarized as follows:

The pedigree method

1. Selecting the parents with the view of combining their desirable characters

in a single variety.

2. Making the cross.

3. Growing the F_2 to F_5 generation plants individually spaced so that selection is possible.

4. Studying the progeny by growing seed of individual plants in progeny rows.

5. Placing homozygous types in yield trials, replicated.

6. Increasing and distributing new varieties of promise.

The method may be illustrated by some work now under way in the breeding of improved varieties of oats and wheat as carried out in Minnesota. At present, we are trying to combine resistance to three major diseases and desirable agronomic characters in a single variety of oats. As crossing is difficult in oats the method of making a few crosses followed by selection during the segregating generations seems a desirable plan. The first important step is the selection of the parents.

Parents in oat crosses

Anthony or Iogold	Bond
*Good yield	Fair yield
*Resistance to stem rust	Susceptibility to stem rust
Susceptibility to smuts	*Resistance to smuts
" " crown rust	*Resistance to crown rust
" " drought	* " " drought
Fair straw	*Strong straw

*Characters desired

The crosses from F_2 to F_5 were grown under conditions of disease epidemic for crown rust, stem rust and smuts. Approximately 1000 lines, with a total of 50,000 plants individually spaced, were grown and examined each year. A knowledge of the mode of inheritance has aided in obtaining the combination of characters desired. A condensed summary of the mode of inheritance of important characters, taken from the studies of Hayes, Moore and Stakman (9), is given here.

Inheritance in oat crosses

1. Crown rust, F_1 resistant, F_2, 9 resistant:7 susceptible
2. Stem rust, F_1 " , F_2, 3 resistant:1 susceptible
3. Smuts. Resistance dominant in F_1, 3 major genes.
4. Spikelet disarticulation. F_1 sativa base, F_2 3 sativa base:1 byzantina base.
5. Floret disjunction. 2 major genes. Byzantina type dominant.
6. Basal hairs. Sativa type dominant, F_2, 3 sativa type:1 byzantina type. Close genetic linkage between genes for 4, 5 and 6.
7. Yield is dependent upon multiple factors. Selection for seed plumpness, stooling, and vigor of plant aids in selecting high yielding genotypes.

It seems unnecessary to emphasize the value of a knowledge of the mode of inheritance of these characters as an aid in breeding. Such information aids the breeder in a selection of homozygous strains with the combination of characters desired. Cultivated oats, like wheat, are hexaploids and have 3 sets of 7 pairs of chromosomes or 21 haploid chromosomes in all. The inheritance of spikelet disarticulation, while approaching a 3:1 ratio in F_2, gave some F_3 segregating lines with wide deviations from this ratio. Similar deviations from expectation have been obtained in wheat. It is important for the breeder to know that meiotic instability is more frequent in some strains and hybrids of wheat and oats than in others as emphasized by Powers (15) and Myers and Powers (13) and that selection for regularity of behavior leads in some cases at least to greater genetic stability. Changes in pairing behavior, whereby a chromosome of one set of 7 chromosomes may pair in crosses with those of another set, explain one of the causes at least of meiotic instability.

One of the important contributions of cereal breeders and pathologists has been the development of stem rust resistant varieties of wheat. The isolation of physiologic races of disease organisms is a genetic application. Over 150 such specialized races of stem rust are now known. The breeding of rust resistant wheat has been greatly simplified by the discovery of a type of "mature-plant resistance" that in the Northwest, under field conditions from heading to maturity, causes certain varieties to be resistant to all physiologic races of black stem rust, even tho they may be susceptible to certain prevalent races in the seedling stages.

A brief history of the development of Thatcher wheat, introduced in 1934 by the Minnesota Agricultural Experiment Station, may be of interest (Hayes and others) (9). It resulted from combined studies of plant breeders, plant pathologists and cereal chemists. During the breeding program many varieties and hybrids of wheat were grown under rust epidemic conditions in a rust nursery using prevalent races of the rust organism. Marquis was crossed with a stem rust resistant durum wheat in 1915. From this cross three selections were obtained that resembled common wheat and that were resistant to stem rust under field conditions. In 1918, Kanred winter wheat, a variety immune to many races of stem rust but susceptible to others, was crossed with Marquis and from this cross strains were selected that combined the immunity of Kanred to certain races of stem rust with the spring wheat habit of Marquis. A cross between selections from these two crosses was made in 1921, i.e. a selection of Marquis x Iumillo was crossed with a selection from Marquis x Kanred. Thatcher, selected from this double cross, combines the desirable milling and baking qualities of Marquis, with the immunity of Kanred to certain stem rust races and with resistance to many races in the mature plant stage from heading to maturity obtained from the Iumillo durum parent.

Before introducing Thatcher it was tested extensively under stem rust epidemic conditions and equally careful studies were made of yielding ability and milling and baking quality. Yields in bushels per acre at the Crookston and Morris branch experiment stations from 1929 to 1938, inclusive, and in the years of severe stem rust epidemics in 1935, 1937 and 1938 show clearly the value of stem rust resistance.

The yield of Thatcher and of other varieties given in table 1 shows clearly the value of stem rust resistance in 1935, 1937 and 1938 when there were severe epidemics.

Table 1. Yields in bushels per acre of Thatcher and of other standard varieties.

	1929-38			1935, 1937, 1938[d]		
	Crookston	Morris[a]	Average	Crookston	Morris	Average
Marquis	18	15	17	8	8	8
Thatcher	26	24	25	25	32	29
Ceres	22	18	20	14	14	14
Hope[c]	21	20	21	17	23	20
Reward	21	18[b]	20	18	20[b]	19

a - no data in 1933.
b - comparable average, Reward not grown in 1934.
c - comparable average, Hope not grown in 1938.
d - severe rust epidemics occurred these three years.

The Backcross Method for Self-pollinated Crop Plants

The backcrossing method is now being used widely by breeders because, through its use, one can retain the many desirable characters of one variety and add the characters that it lacks by crossing and selection. Backcrossing has been used extensively by animal breeders. It was suggested by Harlan and Pope (6) in 1922 for use with self-pollinated crop plants. An appreciation of its value is general among corn breeders who are familiar with convergent improvement, which is equivalent to double backcrossing. Its genetic value is dependent upon the obtaining of the genetic complement of the recurrent parent in the 1st, 2nd, 3rd, etc., generations of backcrossing according to the progression 1/2, 3/4, 7/8, etc. The backcross method will be illustrated in relation to wheat breeding. Its applicability is illustrated as follows:

Backcrossing as a method of breeding

1. Selection of parents.

   A. A variety with desirable characters but lacking one or two characters that are dependent upon only a few genetic factors.
   B. A variety containing one or two of the desirable characters that are lacking in (A).

2. Backcross the F_1 and succeeding generations to (A) selecting for the one or two desirable characters of B.

3. Select in self progeny until desirable homozygous strains are obtained.

Its use may be illustrated by the improvement of Thatcher through crossing with Hope, primarily to add leaf rust resistance and retain stem rust resistance. Thatcher is the standard for yielding ability, desirable agronomic characters and milling and baking value. It is not as stem rust resistant as Hope and Thatcher is very susceptible to leaf rust. The following information was furnished by Dr. E. R. Ausemus of the Division of Cereal Crops and Diseases, U. S. Department of Agriculture, who is stationed at University Farm, St. Paul, and who has charge of the wheat breeding program.

History of backcross (Thatcher x Hope) x Thatcher

Year	Place	Plan
1930	Field	Original Cross
1930-31	Greenhouse	1st backcross
1931	Field	2nd "
1932-37	Field	Pedigree selection

Leaf rust epidemics only in 1932, '35
Stem " " each year.

Yield in bushels per acre, test weight, and leaf rust reaction are given in table 2 from trials made in 1938 when there was a severe rust epidemic in the Northwest spring wheat area.

Table 2. Yield in bushels per acre and test weight, rod-row replicated trials University Farm, 1938. Leaf rust reaction in rod rows (Agron.) and in the rust Nursery (R.N.).

Variety	Yield bu.	Test wt.	Rust Percent			
			Leaf		Stem	
			Agron.	R.N.	Agron.	R.N.
Thatcher	18	47	70	80	T	3
B.C., II-31-2	31	55	2	T	T	T
" -6	30	54	T	5	T	T
" -14	32	54	3	T	T	T

Briggs (2,3) in California, has used the backcross method extensively in breeding improved varieties of wheat. He uses desirable adapted varieties of wheat as one parent and has added bunt resistance by backcrossing and selection.

The few illustrations that I have given show how genetic principles have been adapted rather generally by the plant breeder interested in small grains. Similar illustrations could be given by the score for other self-pollinated crop plants.

Development of Standardized Breeding Methods with Corn

With corn, the most important farm crop grown in United States, the breeding of improved hybrid varieties has had the most far-reaching effect of any work in crop improvement in the present century. Standardization of breeding methods, based on genetic principles, has played a large part in the success that has been attained. The studies of East, at the Connecticut Experiment Station, and of Shull at Cold Spring Harbor, were started in 1905. Shull in 1909 suggested a method of using crosses between inbred lines. It was my good fortune to work under East's direction at the Connecticut Agricultural Experiment Station starting in 1909. A statement of his that seemed to me to be very significant is quoted as I remember it. He said, "I started a study of the physiology of inheritance in maize, believing that a knowledge of principles was necessary in the formulation of a logical method of breeding." A bulletin published in 1912 summarized the effects of self fertilization in corn. Hybrid vigor was discussed in relation to evolution and plant breeding. The following statements were taken from this bulletin.

Effects of self fertilization in corn
(After East & Hayes)(5)

1. Loss of vegetative vigor has followed continued self pollination in all inbred lines.
2. Inbred lines exhibit differences in many normal characters. Example: long vs. short ears.
3. Some pure strains are so lacking in vegetative vigor that they can not be propagated.
4. Continued inbreeding leads to purity of type.

All inbreds so far obtained in field corn are less vigorous than open-pollinated corn or a vigorous hybrid.

It will be noticed that the ears of the inbreds are smaller in all cases than the ear of the F_1 cross. In fact inbreds now available do not yield sufficiently well to make the use of a single cross feasible as a commercial method of seed production. Before illustrating methods of breeding, the mendelian explanation of heterosis, or hybrid vigor, will be outlined.

The Mendelian Explanation of Hybrid Vigor

Keeble and Pellew (12) in 1910 gave the first mendelian explanation of heterosis in a cross in peas. The two parents were medium in height; the one had thick stems and short internodes, the other had thin stems and long internodes. The F_1 showed complementary action of the two genes and was taller than either parent. At this time the large number of genetic factors involved in the inheritance of some characters was unappreciated, and for this reason Keeble and Pellew's explanation of hybrid vigor was not widely accepted. It was not easy to see why it was so difficult to obtain new forms breeding true for the extreme vigor of F_1. In 1917 Jones advanced a theory of heterosis based on the dominance of linked growth factors. The more important feature of this extension seems to me to be the large number of factors responsible for many normal characters. Numbers alone make it difficult to obtain all necessary factors in a single homozygous variety. Linkage adds to this difficulty. The dominant linked growth factor hypothesis appears to accord with the available evidence.

Heterosis, or hybrid vigor, is common throughout the entire plant kingdom. As a rule, heterosis is not so common or striking in crosses between varieties or species of self-pollinated plants as in crosses between inbred lines of the cross-pollinated group. This is to be expected on the basis of the mendelian explanation of hybrid vigor, for varieties of self-pollinated plants, on the average, are relatively more vigorous than inbred lines of cross-pollinated plants. Nature and man have been selecting desirable varieties of self-pollinated plants throughout the ages. If the mendelian hypothesis of hybrid vigor is the correct one, it should be possible, as I have outlined, to breed better inbred lines of cross-pollinated plants than are now available and with corn considerable progress has been obtained in this direction.

According to the present viewpoint, many economic characters are the result of the interaction of multiple factors under particular conditions of environment and in crosses between two inbred lines of corn it seems probable that a considerable number of factors in a heterozygous condition are responsible for the hybrid vigor of the F_1 generation. Certain inbred lines of corn

when crossed with other inbred lines or with a commercial variety seem to have better combining ability, that is, give greater hybrid vigor, than other inbred lines which in themselves seem equally desirable, and there seems to be a growing body of evidence that combining ability is an inherited character. In one experiment with 110 inbred lines of corn, careful studies were made of 14 characters of the inbreds in relation to the combining ability in inbred-variety crosses using the open-pollinated variety, Minn. 13, as one parent in each cross. Twelve of the 14 characters of the inbred lines were positively and significantly correlated with yielding ability in the inbred-variety crosses. Table 3 lists the characters of the inbred lines used in the study and presents correlation coefficients for all possible relationships including correlations between 14 characters of the inbreds with the yield of inbred-variety crosses designated as 15 in the table.

Table 3. Total correlations between 12 characters of the 110 inbreds and yielding ability of inbred variety crosses (Hayes and Johnson)(8)

Characters correlated*	2	3	4	5	6	7	8	9	10	13	14	15
1	0.5118	0.6081	0.4819	0.6465	0.6193	0.5469	0.3831	0.3741	0.2230	0.0731	-0.0591	0.4742
2	---	0.7560	0.4419	0.4817	0.4294	0.3959	0.2588	0.1855	0.3568	0.2549	0.0812	0.2717
3	---	---	0.4324	0.5388	0.5025	0.4133	0.3522	0.3317	0.2201	0.1512	-0.0074	0.4110
4	---	---	---	0.4954	0.4417	0.4797	0.3959	0.2893	0.1847	0.2040	0.0815	0.2889
5	---	---	---	---	0.7623	0.5095	0.6013	0.4052	0.2085	0.1484	0.0352	0.4486
6	---	---	---	---	---	0.5545	0.7424	0.3896	0.2894	0.1947	0.0320	0.5430
7	---	---	---	---	---	---	0.5355	0.2384	0.2674	0.2065	0.1549	0.4069
8	---	---	---	---	---	---	---	0.2559	0.2245	0.2025	0.0683	0.4463
9	---	---	---	---	---	---	---	---	0.1990	-0.0029	-0.0342	0.1902
10	---	---	---	---	---	---	---	---	---	0.3451	0.3202	0.2566
13	---	---	---	---	---	---	---	---	---	---	0.6403	0.2474
14	---	---	---	---	---	---	---	---	---	---	---	0.2768
15	---	---	---	---	---	---	---	---	---	---	---	---

Significant value of r for P of .05 = 0.188
Significant value of r for P of .01 = 0.246

*Key to characters:

1 Inbred date silked
2 Inbred plant height
3 Inbred ear height
4 Inbred leaf area
5 Inbred pulling resistance
6 Inbred root volume
7 Inbred stalk diameter
8 Inbred total brace roots
9 Inbred tassel index
10 Inbred pollen yield
13 Inbred yield index
14 Inbred ear length
15 Inbred-variety cross yield

From this study it was found that the multiple correlation between 12 of these characters in the inbreds and yield in the inbred-variety crosses was .67. Date of silking was held constant and a partial multiple correlation coefficient was found where the multiple correlation R, holding constant date of silking, is obtained from the following formulae:

$$1 - R^2_{15.2,3,4,5,6,7,8,9,10,11,12}\,|1| = \frac{1-R^2_{15.1\text{------}12}}{1-R^2_{15.1}}$$

The computed value of R in this case was 0.5310.

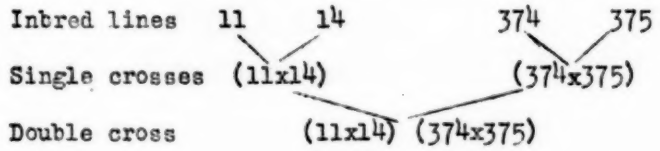
These results show that the characters of inbred lines which are responsible for their relative vigor of growth are also to a considerable extent responsible for the combining ability of the inbreds themselves, as measured by yield in inbred-variety crosses.

The mendelian explanation of hybrid vigor is essential in an understanding of breeding methods with cross-pollinated crop plants. If the explanation is a correct one it would seem possible to breed improved inbred lines that approach homozygosity and that approach the F_1 in vigor of growth. With different cross-pollinated plants the difficulties would seem to be in direct relation to the number of growth factors involved, i.e., the extent of heterozygosity. Throughout the corn belt most and perhaps all corn breeders are endeavoring to obtain more vigorous inbred lines. The breeding methods available are not greatly different than those that have been illustrated with small grains but may be repeated here for corn. Before discussing the breeding of improved inbreds, the commercial value of three-way and double crosses will be illustrated.

Commercial Value of Three-way and Double Crosses

Two types of crosses are being utilized by the commercial grower, the three-way and double cross. A three-way cross utilizes three inbred lines and a double cross is made using four inbreds. Minhybrid 301 illustrates a three-way cross that has been grown extensively in southern Minnesota. Minhybrid 403, a double cross, also has been grown extensively.

The double cross plan is illustrated for Minhybrid 403.



Comparative yields of Minhybrids 301 and 403 and commercial varieties illustrate the value of the method. Ability to withstand lodging and resistance to diseases such as smut and ear and stalk rots are some of the reasons why hybrids are more desirable than commercial varieties. The comparative yields given in tables 4 and 5 indicate rather clearly the value of hybrids to the commercial grower. The yields in table 4 represent results from demonstration trials where the hybrids were planted in strip plots in commercial fields. The results in table 5 are from randomized block trials, replicated five times at each location. Murdock was used as a standard open-pollinated variety. All tests are on the basis of bushels per acre, 14 percent moisture basis.

Table 4. Yield in bushels per acre of Minhybrids 301 and 403 compared with farm varieties.

	Minhybrid 403	Minhybrid 301
No. of trials	85	454
Yield of hybrid	58.3	54.6
Yield of farm variety	49.7	46.6
Increase - bushels	8.6	8.0

Table 5. Yield in bushels per acre of Minhybrids 301, 403 and Murdock, 1937-38.

Location (county)	Minhybrid 301	Minhybrid 403	Murdock
Brown-Cottonwood	60.1	62.5	50.2
Rock	66.2	70.6	54.1
Waseca-Faribault	63.0	66.2	53.1
Fillmore-Houston	68.8	72.4	57.3
Average	64.5	67.9	53.7
Bu. increase over Murdock	10.7	14.2	

The data given in tables 4 and 5 show clearly the value of these two hybrids in comparison with open-pollinated varieties that are similar to these hybrids in date of maturity.

Breeding Improved Inbred Lines of Corn

Two methods of breeding improved inbred lines of corn are being used rather extensively in the Corn Belt. These are backcrossing and convergent improvement.

An undesirable character of the three-way cross, Minhybrid 301, is the susceptibility to smut of the inbred B164. This inbred has been changed by backcrossing. The method may be illustrated as follows:

Improvement of B164 by backcrossing with particular reference to smut resistance

B 164	Early inbred, C37
Smut susceptible	Smut resistance

Method

1. (B164 x 37) x B164
2. [(B164 x 37) x B164] x B164
   Selection in 1 and 2 for smut resistance.
3. Self pollination and selection (2 years).
4. Select a desirable smut resistant line resembling B164.

In a field trial in 1938 and 1939 several such lines were obtained that were highly smut resistant in comparison with B164.

Convergent improvement, first suggested by Richey (16) in 1927 (equivalent to double backcrossing), is a method of improving each of two inbreds without modifying their combining ability when crossed together. It may be illustrated with two of the inbred lines used in Minhybrid 403. Some of the differential characters of the inbred lines 11 and 375 are given here.

Characters of the parental inbreds

11	375
Smut susceptible	Smut resistant*
Large seed*	Small seed
Premature germination	Good quality seed*
Fair root system	Excellent root system*

*Characters desired

The methods followed are given in outline form.

Convergent improvement

1.	1st backcross	(11x375) 375	(11x375) 11
2.	2nd "	(11x375) 375_2	(11x375) 11_2
3.	3rd "	(11x375) 375_3	(11x375) 11_3
		Select for seed size.	Select for smut resistance.
			" " good seed quality.
			" " strong root system.

4. Self pollination and selection for characters desired (2 years).

The inbred parents 11 and 14 were improved in standing ability and in smut resistance. Inbred line 11 was improved in quality of seed while inbred 14 was improved in seed size and in ear length. Inbreds 374 and 375 were improved in ear type.

Another method used extensively in Minnesota to breed improved inbreds is the so-called pedigree method illustrated as follows, which has been described by Hayes and Johnson (8).

Breeding improved inbreds by the pedigree method

1. Select inbreds that excel in the characters desired.
   ex., one parent resistant to smut, the other to lodging.

2. Make several crosses of unrelated inbreds.

3. Continue selection in self-pollinated lines for smut resistance, strength of stalk and other desirable characters for 5 or 6 years.

4. Combine the better lines using crosses between lines of different genetic origin.

Introduced inbreds that excelled in strength of stalk were used as one parent of several of the original crosses. As standing ability was difficult to select in commercial varieties, later maturing inbreds with good standing ability were introduced from other breeders.

These introduced inbreds were crossed with early maturing inbreds selected in Minnesota, and selection was practiced during the segregating generations. Some characters of selection value that have been used in making selections from F_3 to F_6 are of interest.

Some characters of selection value

1. Length of ear and ear production.
2. Period of maturity.
3. Vigor of plant.
4. Well developed root system.
5. Smut resistance.

After obtaining the best possible inbreds (110 were selected at University Farm and about the same number were available from the Waseca studies) the following methods have been used in further work.

Selecting crosses from inbred lines available

1. Determine best combiners in inbred-variety crosses.
2. Make all possible single crosses between unrelated lines.
3. Predict yield of double crosses.
4. Make yield trials of actual double crosses.

Jenkins (10) compared various methods of testing the combining ability of inbred lines in double crosses using single crosses as one method of predicting the yielding ability of double crosses. Doxtator and Johnson (4) made a further study of single crosses as a means of predicting the yield of a particular double cross. The following data is taken from the work of Anderson (1) and shows how single crosses are used to make such a prediction. The yield of a particular double cross may be determined with accuracy from the average yield of the four single crosses not used as parents in the double cross. From any four inbred lines six single crosses can be made and three different double crosses. One of these three double crosses frequently yields more than the other two.

The inbreds that yield well in inbred-variety crosses may be tested in single crosses and their yielding ability in double crosses predicted, as illustrated from data presented by Anderson.

Method of predicting double cross yields from single cross data

(23x24) x (26x27)

(23x26)	62.6
(23x27)	70.8
(24x26)	65.6
(24x27)	72.1
Av.	67.8

(23x26) x (24x27)

(23x24)	41.7
(23x27)	70.8
(26x24)	65.6
(26x27)	64.2
Av.	60.6

(23x27) x (24x26)

(23x24)	41.7
(23x26)	62.6
(24x27)	72.1
(26x27)	64.2
Av.	60.2

A comparison of actual and predicted yields of double crosses by Anderson is given to show the value of the method.

A comparison of actual and predicted yields (after Anderson)

Lines combined	Bu. per A.	
	Actual	Predicted
23,24,26,27		
(23x24) x (26x27)	68.8	67.8
(23x26) x (24x27)	62.4	60.6
(23x27) x (24x26)	62.0	60.2
23,24,26,28		
(23x24) x (26x28)	65.0	65.5
(23x26) x (24x28)	59.8	58.0
(23x28) x (24x26)	56.0	58.5

(continued)

23,24,27,28		
(23x24) x (27x28)	71.1	69.2
(23x27) x (24x28)	58.1	59.4
(23x28) x (24x27)	58.0	60.4
Diff. for signif.	5.26	3.41

Inbred lines selected at Waseca and University Farm were combined in single crosses using unrelated lines. The inbreds used in one cross illustrate the method without the necessity of detailed description. It will be noted that inbreds A96, A163, A116 and A131 were selected from crosses between inbreds (64xH), (43x47), (49x9) and (11-28 x 15-28), respectively. After crossing, self pollination and selection was practiced six years before inbreds were selected for use in crosses. A96, A163, A116, A131 and other inbreds used as parents of double crosses were first tested for combining ability and only good combiners were selected.

Genetic diversity of inbreds

Original parent inbreds	Source
64	N.W. Dant
H (Reid's)	From Holbert, Ill.
43, 47, 49, 11-28	Four Minn. #13 inbreds
9	Wis. Golden Glow
15-28	Rustler

Inbreds selected	Origin
A 96	64 x H
A163	43 x 47
A116	49 x 9
A131	11-28 x 15-28

The yielding ability in a double cross in bushels per acre on a 14 percent moisture basis and the moisture percentage (% M) at harvest, used to show relative time of maturity, is illustrated in the following summary for the double cross (A96 x A163) x (A116 x A131).

Method of predicting yield and actual results

Av. yields 4 stations, 3 replications per station, 1938

59.1 bu. (A96xA163)	47.0 bu. (A116xA131)	
Cross	Bu.	% M.
A96 x A116	57.6	20.5
" x A131	58.7	22.0
A163 x A116	65.3	20.4
" x A131	68.2	22.5
Av.	62.5	21.4
Minhybrid 401	60.0	24.2
" 402	54.3	21.3

From this summary we conclude that the double cross (A96 x A163) x (A116 x A131) may be expected to yield as much or more than the later maturing hybrid, Minhybrid 401, and mature as early as Minhybrid 402.

Four double crosses that were tested in southern Minnesota in 1938 and 1939 illustrate many other comparisons that have been made in recent years. Yield in bushels per acre, 14% moisture basis, for predicted doubles grown in 1938, yield in bushels per acre from actual doubles grown in 1939, and moisture percentage at harvest is given in table 6. The results given are an average of trials in three or four locations in randomized blocks with three replications per location.

Table 6. Predicted yield of double crosses in 1938 and actual yield 1939, compared with standards, Minhybrids 401 and 403.

	Yield bu.*			Moisture %*		
Double Cross	1938	1939	Av.	1938	1939	Av.
(42x144) x (57x92)	72.6	77.3	75.0	28.6	29.4	29.0
(134x144) x (57x92)	80.7	82.9	81.8	29.6	28.4	29.0
(122x134) x (57x144)	80.2	83.0	81.6	30.8	27.0	28.9
(134x375) x (122x30)	83.1	86.4	84.8	35.8	33.2	34.5
Minhybrid 401	62.5	59.7	61.1	28.8	27.3	28.1
" 403	79.4	71.8	75.6	31.6	32.3	32.0

*1938 yield and moisture predicted from results from F_1 crosses.
1938 yields and moisture obtained in regular tests of these double crosses.

These results illustrate the many cases where prediction of the yielding ability of double crosses from yields of singles may be used. This greatly simplifies the testing of many double cross combinations for the predicted yields of over one million double crosses can be obtained from testing 1770 single crosses, that in turn can be obtained from all possible combinations between only 60 inbred lines.

A study of F_1 crosses between the inbreds available has shown the importance of genetic diversity of inbred lines used in double crosses. Three groups of lines based on relationship were used and the yields of single crosses were compared on the basis of origin. The three groups on the basis of origin are illustrated as follows.

Original Cross	Inbred cultures selected
A48 x H	A94, A96
A9 x A26	A102, A111, A116, A122, A124
A9 x A39	A99
A39 x A26	A136, A143, A145

Group I, no parents in common, i.e., A94 x A102, etc.
" II, one parent in common, i.e., A102 x A99, etc.
" III, both parents in common, i.e., A 102 x A111, etc.

Results of yield trials from an average of three localities are given in table 7.

Table 7. Yield of single crosses in comparison with standards, Minhybrids 401 and 402, in relation to the origin of the inbred lines. Randomized block trials average of three locations, 3 replications per location.

Group origin of inbreds	Single crosses as desirable as Minhybrids 401 or 402a	Less desirable
	No. of single crosses	
1. Unrelated	28	15
2. One parent in common	6	9
3. Two parents in common	1	14

[a]Minhybrids 401 and 402 have proven desirable double crosses in North Central Minnesota from extensive yield trials.

These results show that single crosses between unrelated inbreds yield better, on the average than either group 2 or 3. When both inbreds were selected from an inbred cross with two parents in common, most of the single crosses were low in yielding ability. Genetic diversity of inbreds used in making single crosses seems essential in relation to obtaining high yielding single crosses.

Single crosses from combinations of unrelated inbreds were tested in yield trials and the yields of predicted double crosses were determined. From each 4 inbred lines 3 predicted double crosses can be made and as a rule one of these appears somewhat superior to the other two as has been emphasized. In the summary in table 8 only the best double cross from each 4 inbred lines was used.

Table 8. Yields of predicted double crosses using unrelated inbreds compared with standard double crosses. Predicted double crosses of comparable maturity to Minhybrids 401, 301, or 403. Those yielding as well or better than standard double crosses are summarized as E, early, M, medium maturity, etc. Those classified as undesirable were lower in yielding ability than standard Minhybrids 401, 301 and 403.

Cross	E	M	L	V.L.	Undesirable
Group		No. of lines in each group			
Early	10	7			
Medium	2			2	
Late	2	7	10	4	5
E x M	11	10	7		12
M x L		3	21	12	4
Total	23	29	38	18	21

Out of a total of 129 such double crosses 108 were equal or superior to the standard recommended hybrids. The breeding methods used, therefore, show what can be accomplished by the use of genetic methods in planning a definite breeding program.

Some Concluding Remarks

Continued intensive studies of genetics and other plant sciences and their aplication to breeding problems may be expected to yield handsome dividends in the development of more efficient crop plants and more efficient breeding methods than are now available. While much has been accomplished already, the possibilities of further improvement seem almost unlimited.

I have discussed the breeding of self-pollinated crop plants and of corn because breeding methods, with these crops, have become standardized to such an extent that it is possible in many cases to plan the breeding program with the definite expectation of obtaining certain desired results. I have spent considerable time in presenting methods of breeding with corn because some of the principles learned seemed to have a direct bearing on the program for improvement of other cross-pollinated plants such as sugar beets.

The breeder of grasses has accepted, for the time being at any rate, the English plan of strain building. Instead of breeding many varieties this plan consists of isolating favorable germ plasm and the recombining in a single variety of the best germ plasm available. When self pollination is possible inbred lines may be isolated. This makes possible the isolation of relatively pure breeding types. The combining ability of such inbreds can be determined by methods similar to those used with corn. Synthetic varieties can be developed from the use of inbreds when such methods prove feasible. It would seem desirable to test combining ability of the inbreds and use in the synthetic variety only those that show the greatest hybrid vigor. It is possible that methods may be developed with some crop plants, such as sugar beets, for the more direct utilization of hybrid vigor by using first crosses between inbred lines for the commercial crop. Several members of your association have emphasized the desirability of this plan.

In our studies with corn at Minnesota, we have learned the importance of selecting inbreds for use in a particular double cross that are as genetically diverse as possible. In presenting the history of sugar beet improvement, Dr. Coons has pointed out that sugar beet varieties are rather closely related from the standpoint of their origin. Some method of adding greater diversity of genetic origin may be important in sugar beets in relation to the utilization of hybrid vigor in the breeding of improved varieties.

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SOME MODERN ADVANCES IN THE STUDY OF PLANT NUTRITION

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Two types of discussion might be envisaged in preparation for this occasion. One type would be concerned with the intensive development of some specialized phase of research in plant nutrition; the other with a general survey of a broader field. After consultation with a representative of your program committee I decided to attempt the latter. It is my understanding that many technical interests are represented in this association and that perhaps only a relatively small group will have spent much time in the study of the literature of the aspects of plant nutrition with which I shall deal. From those who are specialists in this field of study I must ask forbearance while I discuss questions already familiar to them. I should also like to explain, in this introductory remark, that a considerable part of my illustrative material will be taken from research conducted at the University of California Agricultural Experiment Station, not because I have any wish to magnify this particular work, but because it seems to me that a more effective presentation of a subject can be made, if the speaker draws heavily on the experience with which he has had a more or less immediate contact.*

My general theme is that of certain basic research underlying the management of the soil as a medium for supplying essential mineral elements for plant growth. It might be anticipated that I should therefore at once embark on a discussion of the subject of "plant foods." But it seems to me that this conventional approach may be misleading. The term "plant foods" itself as used to designate a few of the elements derived by the plant from the soil, although too well established to be displaced, may give us a very incomplete and inaccurate impression of our general problem. We are in the danger of relegating too far in the background of our thinking the physiology of the plant. We grow crops because the green plant has the power of synthesizing from simple substances, principally carbon dioxide and water, organic compounds which not only serve as its own food and structural material, but also as the food of animals, and as industrial products.

The basis of this synthetic power resides in that unique process, photosynthesis, by virtue of which the radiant energy of sunlight is fixed and thus the energy imported from outside our planet made available. Time worn as the idea may be, it is worth repeating that animal life, and civilization, in both its beneficient and malevolent manifestations, is in the present stage of scientific development, utterly dependent on photosynthesis, as it occurs from year to year or as it has occurred in past geological ages. There is not yet any foundation for the picture sometimes imagined by popular writers, of great factories gathering sunlight on the roof and producing a stream of sugar. Indeed the sucrose of the plant has not yet been synthesized by even the most intricate processes of the laboratory. You may be confident that you are engaged in one of the most fundamental occupations of mankind.

It is true that the process of photosynthesis has a low over-all efficiency. Usually less than 1% of the total radiant energy of the sun falling on any given area will be stored in the plant. But it is necessary to recall that the true biological efficiency of this process must be measured in terms of energy absorbed by the surface of the choroplastid where the photosynthetic

*A series of lantern slides was presented but the illustrations are omitted from this publication. No attempt is made in this general discussion to give literature citations. A large bibliography would be required.

process occurs. Considered in this way the efficiency of utilization of energy may be remarkably high, for example, 60% or 70%, according to the results of some early investigations. But recent scientific reports reveal divergent evidence as to just what degree of efficiency the photosynthetic process can attain. Some conclude that the efficiency is much lower than that mentioned above. Many difficult questions of technique and of the interpretation of results arise. There are, however, indications, of special interest to our present discussion, that the efficiency of the photosynthetic process may vary with the status of the plant in respect to mineral elements and may be dependent in part on the adequacy of the amounts available to the photosynthetic system of elements like iron, manganese, copper and zinc which function on a microscale. I shall later say something further of elements in this category.

Understanding as we do the role of sunlight energy in the synthesis of plant products, it is worthy of remark that so little effort is made by agronomists or horticulturists to measure and record the intensity and quality of the sunlight energy available to crops in their diverse locations, together with other interrelated climatic data. The importance of this general question was impressed on my mind last summer during a visit to the Hawaiian Islands. As some of you know, in these islands, extraordinary differences in rainfall and in sunlight conditions may occur within short distances. The Sugar Planters Experiment Station has conducted some experiments on the growth of sugar cane at two localities, one of high rainfall and low sunlight values, the other of relatively low rainfall and high light values. Temperature differences are not very great. Soil was transported from each locality to the other, so that plants could be grown in the two types of soil under the two climatic conditions. At the high-light station the cane plants produced several times as much sugar as at the low-light station as a result of both higher yields and higher percentages of sugar, when plants were grown in amply fertilizer soil from either station. In other words, the potentialities of fertilizer applications to increase plant growth and sugar synthesis could not be understood without reference to climatic conditions.

I have spoken of the process of photosynthesis, a special function of green plants, but there is another physiological process that occurs in all living organisms, namely — respiration, which must always receive consideration along with photosynthesis. Respiration, in contrast to photosynthesis, leads to a loss of carbon and the growth of the plant with increase of its dry weight is a net result of the two opposing processes.

The mineral nutrition of the plant can be understood only on the basis of the interrelations between mineral elements absorbed by the plant and the synthesis of organic constituents or their destruction -- photosynthesis and respiration. A conspicuous illustration of the general idea is found in the utilization of nitrogen, usually absorbed by the plant as nitrate. Long ago the concept of nitrogen-carbohydrate relations in the plant was formulated, but at an earlier period there often existed lack of appreciation of the complexity of these relations and attempts were sometimes made to interpret them in a too narrow way. An important modern advance in our knowledge of plant nutrition is provided by research workers in the fields of plant bio-chemistry and plant physiology, who have made a good beginning in the study of the chemical processes involved in the reactions of carbohydrates, organic acids and absorbed nitrogen. In simple terms we may say that by altering the balance of these reactions, the plant may be profoundly influenced in its type of growth with respect to processes of reproduction or of storage of sugar or other carbohy-

drate reserves. Therefore the intake of nitrogen and the climatic factors affecting photosynthesis and respiration, in relation to vegetative growth, reproduction and storage of sugar or other carbohydrates, require evaluation. It should be recalled that while photosynthesis is accelerated by increasing temperature, within certain temperature limits, under conditions of darkness or deficient light, only the process of respiration, resulting in loss of carbon, is increased with increase of temperature. As another factor, recent evidence shows that excess nitrogen may greatly increase the rate of respiration in plant tissues.

An illustration of nitrogen-sugar relations of a type familiar to you may be cited from an experiment on the sugar beet in California. In certain districts in which beets are grown in peat soils, it has been found that the high nitrate level maintained in the soil over a long period results in a great lowering of sugar content. On the other hand, in other experiments with different soils and under other climatic conditions, applications of nitrogen have given increased yields as well as high percentages of sugar. In the latter case the initially high supply of nitrogen was not maintained too long during the season of growth. Another example may be found in certain work being carried on in Hawaii with the pineapple, in which it is sought to control nitrogen fertilization with regard to the stage of growth of the plant and the climatic factors, especially the sunlight factor, as influencing sugar synthesis. It is believed that a large measure of economy has been effected in the use of nitrogen fertilizers.

I raise these questions, which are of course not new ones, because it seems to me worthwhile to suggest that far more investigation is needed of the nitrogen metabolism of plants with the aid of the methods of the biochemist and plant physiologist now under active development. The biochemical experiments of the laboratory would require too much time to describe, but I should like to mention the work at Cornell in which the photosynthesis of apple trees growing under natural field conditions is being successfully studied. Of great interest are the researches of Thomas and Hill in Utah. These investigators have devised ingenious, automatic apparatus for measuring the rate of photosynthesis or respiration in the alfalfa or other plants, as influenced by climatic and other physiological conditions. It can scarcely be doubted that a better understanding of photosnythesis and respiration in relation to nitrogen metabolism has a definite practical interest for problems of soil fertilization. An excellent example is that of the sugar beet.

The mineral elements absorbed from the soil are essential to the processes of photosynthesis, respiration and all other metabolic processes in the plant, but it is likewise true that the absorption of these mineral elements is dependent on the organic metabolism of the plant. It is therefore appropriate to present some principles regarding the absorption of mineral elements by roots. In this presentation it is convenient to eliminate the complexities of the soil from consideration for the moment, and to assume that we are studying plants growing with their roots immersed in a dilute nutrient solution — the method known as water-culture. At an earlier period agricultural chemists and plant physiologists commonly conceived that in such a system the roots absorbed the mineral nutrients by a process of simple diffusion. Sometimes the root was even likened to a collodian bag as far as the absorption of the mineral nutrients was concerned. We know now that any such view is untenable. Actually the root cells normally absorb mineral solutes against concentration gradients and this demands expenditure of energy. The absorption

is a function of living, respiring cells. A supply of oxygen and of organic compounds capable of yielding energy is essential. Further, the temperature of the root must be suitable for the maintenance of the chemical reactions of the living cell at a sufficiently rapid pace and yet not too high to produce excessive respiration.

What is the significance of these conclusions in terms of availability of mineral nutrients? It is this: that availability in its physiological, and therefore practical application, is not merely a question of the presence of the nutrients in the culture medium in proper form and amount, but is just as definitely a question of the physiological status of the root determining its ability to grow, and increase in surface, not excluding that some passive movement of nutrients may take place through injured or physiologically inactive roots, as a result of transpiration.

We are faced then with the general problem of the essential requirements for root growth and activity. In the external environment there must be provided an adequate assortment and supply of oxygen; and in the internal environment, a store of sugar or other labile carbohydrates initially synthesized in the leaf and then transported to the root. Are there other internal or external requirements? This question is now receiving careful study in a number of laboratories. One method of attack is to grow roots from excised root tips in a sterile culture solution of known composition. Sugar is presented to the roots in the solution since the top of the plant cannot supply sugar to the root. Some years ago it was proved by several investigators that tomato roots could be kept growing in this way indefinitely, in certain types of culture solutions. One of the essential components of the solutions was an extract of yeast. Subsequently several investigators independently obtained evidence that one principal reason why yeast extract was necessary was that it contained a vitamin -- known to the animal physiologist as vitamin B_1. This vitamin was found to be indispensable for growth of roots of the species of plants investigated. Later work suggests that still other vitamins or growth substances may be necessary; for example, nicotinic acid, the antipellagra vitamin of the animal physiologist. Such substances exert their effects in amazingly small quantities. A definitive result has been attained from even one millionth of a milligram of vitamin B_1. It is becoming clear that plants do not synthesize vitamins as a philanthropic act for the benefit of the animal. Some, possibly all of these substances, have a role in the plant's own growth.

Let us attempt to summarize these researches on roots in terms of crop growth under natural conditions. The root is the organ by which the plant makes its contact with the soil and the absorption of mineral nutrients depends on the physiological activity of the roots and on their growth and extension of surface, which determines the number of contacts made with soil particles. Since oxygen is necessary for root growth and normal absorption of mineral nutrients the importance of soil aeration at once becomes obvious, with all that this implies in terms of irrigation practice, soil cultivation, and cover crop practices. Sugar and growth substances are required by the roots and these are synthesized in the top of the plant, with the aid of solar energy. Therefore climatic conditions affecting photosynthesis have an influence in determining the relation of the soil to the plant through its root system.

Thus far I have been assuming that roots absorb the mineral nutrients from a simple nutrient solution. As applied to the soil this is the soil solution theory which has for many years usefully served as an interpretation

of the mechanism by which mineral nutrients become accessible to the plant. The concept is that these nutrients are absorbed by roots only after they have first dissolved in the soil solution. Undoubtedly the absorption of nutrients from the soil solution does have a major significance, as is indeed evident from the fact that some important nutrients, especially nitrate, are not adsorbed to any important degree by the colloids of the soil, and the negatively charged nitrate ion is necessarily accompanied in the soil solution by equivalent quantities of positively charged ions such as calcium, magnesium and potassium. Nevertheless, evidence has been obtained by Jenny and Overstreet in our laboratory, and by several other investigators, in favor of the view that an additional mechanism exists for the intake by the plant of certain nutrients which can be held in adsorbed condition by the colloids of the soil. This mechanism has been called "contact" intake of ions. Briefly, the idea is that the roots and soil colloid can make such an intimate contact that ions can migrate through the combined colloidal system of the root surface and soil colloid without having to enter a soil solution phase at all or, in non-scientific language, potassium, for example, can jump from the soil to the plant root. There is a physical-chemical basis for this theory, but its discussion would not fall within the scope of this paper. I may add that some of the experimental evidence has been gained by the use of a new method of research made available by that remarkable development in physics by which many chemical elements can artificially be made radioactive. The radioactive elements become tagged and their movement in the plant or animal can be followed by detection of the radioactivity, for which exceedingly sensitive methods exist. The application of this new tool constitutes one of the important recent advances in the study of plant and animal nutrition.

Much more research will have to be conducted before the full implications of the contact theory of intake of nutrients by plants becomes apparent. It may be said, however, that another reason has been presented for emphasizing the limitations of existing knowledge and the difficulties that arise in devising methods for appraising the availability of nutrients in the soil.

Now that I have outlined some problems of the movement of nutrients into the plant, it is in order to consider the present status of knowledge as to the chemical elements that are indispensable for plant growth. Not very many years ago the prevailing view of students of botany and of plant nutrition was that the plant required, in terms of absolute essentiality, only 10 chemical elements. These were carbon, hydrogen and oxygen and of soil origin, nitrogen, potassium, calcium, magnesium, iron, phosphorus and sulphur. Mazé in France, about 1914, presented certain experimental evidence on the corn plant which indicated that other chemical elements were also essential, but his views received no general acceptance at the time. Then came a period of reinvestigation of this question with the use of highly refined technique. Generally the water culture method for growing plants was found to be best suited for the purpose. Nutrient salts, even of C. P. grade, were repurified, and water for the cultures was distilled and redistilled. With these and other precautions experiments were performed which gave perfectly clear results. The plants studied would not grow normally, or indeed might make scarcely any growth at all, unless supplied with small amounts of boron, copper, manganese, and zinc, in addition to the usually supplied nutrient elements. Still further improvement of technique has enabled two of my colleagues, within the past several years, to obtain evidence strongly supporting the view that molybdenum is also one of the essential elements. We cannot say, however, that the list is closed. It can only be safely asserted, for any particular set of experimental condi-

tions, that chemical elements not deliberately added to the culture medium are needed in quantities not greater than those unavoidably present as impurities. New refinements of technique in the future may disclose still other indispensable chemical elements. In fact, even now there are indications that other elements may be required in minute quantities, such as sodium, aluminum and silicon.

Perhaps some of you would like to raise the query as to whether the same elements are indispensable for all species of higher plants. With regard to boron, zinc, copper, and manganese, this seems highly probable on the basis of existing knowledge. The effects of deficiencies of these elements are so profound as to indicate that they play some universally vital role in the plant's metabolism. For two of the elements, boron and manganese, so many different botanical groups are represented in the investigations already made, that no valid objection can be entered to the extension of the conclusions to species of plants which have not been subject to actual experimental test. For that matter, it has not been shown by actual experiment on every species of plant that potassium is an essential element, but we do not doubt it. It may be true, nevertheless, that some specific mineral requirements do exist. To cite one case, experiments have been made on certain leguminous plants that have an exceptional power to absorb the element selenium, and the suggestion has been proposed that these plants may require selenium for their normal growth, or at least that this element may have a highly beneficial effect. Incidentally, the selenium absorbed by the plant may be highly toxic to the animal which feeds on it.

In the earlier phase of the investigation of elements required by plants in minute quantity one might well have doubted the practical value of the knowledge gained by growing plants in highly purified nutrient solutions. Was it reasonable that deficiencies of elements needed in such minute amounts would occur under ordinary crop conditions?

Today we can answer this question with certainty. In recent years reports have come from many parts of the world to the effect that in some localities nutritional crop diseases have been overcome by the use of boron, manganese, copper, or zinc, as the case may be. Most numerous are the reports of boron deficiencies. As you know, the sugar beet has responded to boron applications in a considerable number of instances, and certain diseases of the beet are caused directly or indirectly by boron deficiencies. Excessive liming of soils may apparently induce boron deficiency in some soils. On the other hand, in California, boron toxicity to crops may occur not infrequently because of too high content of boron in the irrigation water. It is one of the characteristics of elements of this type that, while they are indispensable in minute quantity, they also readily produce injury to the plant at low concentrations.

It is, I think, entirely justifiable to conclude that the researches, in the laboratory and in the field, on chemical elements effective in minute amounts for plant growth, constitute one of the most important of modern advances in plant nutrition. We should be always alert to the possibility that deficiencies of elements of this category may already exist or may develop with continued cropping. Yet a note of caution should be introduced. Not all soils, by any means, require the addition of boron, manganese, copper or zinc. And when a need does exist it may not necessarily follow that the impurities present in some particular form of fertilizer will be effective. The fixing

power of the soil, or power to render such elements inaccessible to the plant, may be such that far larger amounts may be required than would be furnished by impurities present in any standard fertilizer. This point is well illustrated in the treatment in California of the zinc deficiency disease of fruit trees known as "little leaf" or "mottle leaf." Generally the treatment has to be made directly to the plant, as for example, by spraying with zinc containing spray mixtures, because of the great expense and difficulty of soil treatment.

I have made the effort in the foregoing discussion to sketch -- necessarily inadequately -- some general principles and points of view applying to plant and soil interrelations with the emphasis on the physiological approach. In the remainder of the paper, I shall outline certain problems in the same general field of study, but with the emphasis on the soil.

In the fertilization of a soil, we are often inclined to think that we are adding certain nutrients, or "plant foods," and thereby increasing the supply ready for absorption by the plant in proportion to the amounts added. This would only be true if we added the fertilizer to a totally inert medium. But the soil is far from an inert medium. As soon as a fertilizer is added to it the system is disturbed and many chemical reactions take place, and more slowly, microbiological effects manifest themselves. In the laboratory with which I am associated, and in many others, during recent years the old problems of fixation of potassium and phosphate by soils have been re-examined. On some of the theoretical aspects of these problems an entire reorientation has occurred because of new discoveries on the nature of soil colloids. Until comparatively few years ago soil colloids and colloids in general, were regarded simply as matter in a very fine state of division with great development of surface. They were thought of as essentially amorphous. Then came the application of a new tool of research, at least new to the field of soil science — the X-ray diffraction analysis. The X-rays employed are of such short wave length that they can be reflected from planes of atoms and give evidence of the arrangement of these atoms by effects produced on photographic films. Examined in this way, many preparations of soil colloids were shown to be crystalline in the sense that the atoms are arranged according to definite patterns, determined by the laws of valence. Fundamental building units in these crystalline colloids are oxygen, silicon and aluminum. They are present in electrically charged form or crystal lattice ions. I can do more than bring this development to your attention. Its adequate discussion would require a long period and the authority of a specialist in this field of work. I may add that the study of the crystal structure of soil colloids is now becoming one of the active fields of research in soil science and a number of investigators in Europe and America have published reports during the past few years.

The whole field of soil and plant interrelations has been illumined by the steady growth of our understanding of the phenomena of base exchange in soil colloids. We can now perceive a certain unity in the reactions of diverse types of soil, which before seemed to have no relation to each other. Many features of acid soils of humid regions and alkali soils of arid regions are both explicable in terms of theories of base replacement. In the one case calcium ions have been displaced to a greater or lesser degree by hydrogen ions; in the other by sodium ions, with all the important consequences, theoretical and practical, of such ionic interchanges. Researches on base exchange have had a profound influence on liming practices and on methods of reclaiming alkali soils, or of preventing their formation. Guided by the principles of base exchange, my colleague, Dr. Kelley, has successfully reclaimed black alkali soil, which twenty years ago seemed hopeless of change to a crop bearing soil.

In the realm of fertilizer practice we are concerned with the fate of potassium and we know that this element when added to the soil may become fixed and displace equivalent quantities of other bases, calcium, magnesium and sodium, from the colloid system. The potassium so fixed will be available to roots when displaced by hydrogen ions excreted by the roots as carbonic acid, within certain limitations imposed by the degree of saturation of the colloid with potassium and the nature of the other ions held by the colloid. But the researches of recent years have made it evident that the problem is more complex than these statements would imply. In many soils of neutral or alkaline reaction potassium added to the soil may be fixed in what is called for convenience "non-exchangeable form." This means that after fixation the potassium is displaced only with greatest difficulty by chemical reagents and it may become only slightly available to the plant. Consequently all the potash fertilizer added to a soil and unused by the crop is not necessarily stored away in available form for future crops. Also fixation in either replaceable or non-replaceable form will mean that roots developing below the zone of fixation will not benefit by the fertilizer application of potassium except to the degree, perhaps very slight, that potassium is released and moved downward. A practical problem arises then with deep rooted plants, like fruit trees, if potassium fertilization of the soil is needed.

There is also the now well confirmed and interesting observation that in some soils fixation of potassium in non-replaceable form is greatly accelerated by alternate wetting and drying the soil.

If we deal with the potassium naturally present in the soil in an effort to determine its availability by chemical procedures, we are faced by another complexity. As I have just indicated, potassium held by the soil in the so-called non-replaceable form may sometimes be largely unavailable to the plant, but this is not necessarily true. There exist soils from which plant roots can extract potassium in reasonably adequate quantities and yet the chemist in the laboratory finds that to extract by chemical means similar quantities of potassium requires such drastic reagents, or so long a period of leaching, that the methods employed cannot be interpreted as biologically significant. The contact phenomena of root with soil particles, together with the remarkable biological activity of the root in absorbing potassium, are involved in a system which has not so far been successfully imitated in the test tube. We need then feel no surprise if a short-cut method of determining potassium availability often fails to give us the information we should like to have. A great many soils have been examined in California by the Neubauer method, which determines the amount of potassium removed from a given weight of soil by rye seedlings. In many instances much more potassium is removed by the plants than by chemical reagents usually employed in the laboratory to determine potassium availability.

Modern researches on phosphate-fixation also aid greatly in the clarification of the nature of the problem of availability of phosphate to the plant. The fixation of phosphate in the soil may be classified in a general way into two types of processes; fixation by chemical precipitation, with special reference to calcium phosphate, and adsorption fixation by colloids. The latter may imply a high degree of unavailability to most crops, though the degree of saturation of the colloid with phosphate is an important modifying factor. In the category of colloid fixation of phosphate, new evidence has been obtained in the study of kaolinitic colloids. Very finely divided kaolin possesses a remarkably high capacity to fix phosphate and the phosphate thus

fixed is not dissolved by acids of ordinary strength, from the point of view of plant nutrition. Instead it is displaced by hydroxyl ions of an alkaline solution. A type of anion exchange takes place. The phosphate held by the colloid may also be displaced by certain organic acid anions, for example, by citric acid, not because of hydrogen-ion effects, but because of the character of the anion. Some colloidal iron compounds may exhibit similar reactions. Generally of greater importance, in soil systems governed by calcium and phosphate equilibria, are complex buffer effects influencing the solution of phosphate.

The researches on the fixation of phosphate by soils have in themselves great interest for the soil chemist, but in interpreting their meaning for crop production, again we must consider the whole system, which includes the plant. From the same soil one species of plant may secure an adequate supply of phosphate and another may make only feeble growth because of phosphate deficiency. The reason for the differences is far from clear, but several factors readily suggest themselves. One is the length of the season for adsorption of phosphate -- for example -- the period would be much longer for a fruit tree than for a barley plant. Then there are to be considered those internal physiological factors which determine the growth of roots and the number of contacts which can be made with colloidal particles of the soil. Since organic acids have a special property of displacing phosphate from certain colloidal complexes, the question follows if some types of plants secrete — or leave as a residue from root decay -- organic acids in such kinds and amounts as to result in important increases in the supply of phosphate to the root system. Finally, some recent researches have dealt with organic forms of phosphate which may escape fixation in the soil. Whether or not it is feasible to use organic phosphates as fertilizers, the relation of organic matter added to the soil to phosphate availability is important. All these questions of fixation of phosphate and potash have a practical bearing on the methods of fertilizer application. A recent agricultural writer suggests that one of the greatest practical advances in plant nutrition is found in the studies on the proper placement of fertilizers.

I am not sure the plan of this discussion has been a wise one, but I have at least made the attempt in this rapid survey to bring before you for further consideration aspects of investigations of soil and plant interrelations, which seem to me to represent some significant approaches to the general problems of plant nutrition. Perhaps much of what I have said may appear to have little direct bearing on the subject of sugar beet production. My own view would be that the sugar beet industry does have a vital concern with researches on basic principles of plant nutrition. It is true that the growing of crops is not now, and presumably never will be, subject to the precise control of a chemical factory. But we still may entertain high hopes, on the basis of past experiences, that increasing scientific knowledge in the field of this discussion will not fail in due time to yield economic rewards. I like to think also that those engaged in the growing and utilization of crops have an interest in the relation of the plant to its environment apart from considerations of economic gain.

AGRONOMIC PROBLEMS OF THE SUGAR BEET INDUSTRY IN RELATION TO A RESEARCH PROGRAM

by
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In speaking to you whose experience has led each one in his field much farther than I can presume to follow, I wish, first of all, to recognize the great achievements in research that are already to your credit. The foundation for many of the practices now followed in this industry as well as important changes in its conduct have been due in no small part to the effectiveness of your work.

I doubt whether anyone could bring up a problem in connection with the culture and management of the sugar beet crop that has not already received consideration by some member of this group. Yet, who can say that even the oldest of these problems has been fully solved? The answer that appeared so convincing under one set of circumstances may be entirely inadequate when the circumstances themselves are different. A practice, the merit of which appeared so evident in experimental plots, has not passed its final test until its application has been accepted and found feasible.

I hardly remember when I was not interested in the problems of the sugar beet industry, agronomic and otherwise. My first vivid recollections of the sugar beet date back to a 4th of July morning about 1902, when the highway passing the beet field on our home farm was busy with a stream of horse-and-buggy traffic of holiday picnickers while I spent the morning on my hands and knees trying to make one beet grow where two grew before. Right then I decided that growing sugar beets had to justify itself as an economic enterprise, for it certainly had no special appeal as a way of life.

Of course, with the sugar beet, as with any other crop, the keenest interest of grower and handler alike is in the price. However, this discussion has nothing to do with either marketing or politics. It deals with sugar beet culture.

There can be little question that the growing of a crop of sugar beets in any manner in keeping with the American way of farming, becomes most complex in its labor aspects. Heretofore, we have relied largely on agricultural engineers to remove the tedium of hand labor from many of our farm practices. In a large measure they have been successful, so successful that their achievements have often been the object of question on the part of those who would find work for idle hands regardless of the nature of the drudgery involved. From the curing of hay on the clotheslines of Norway, through the beet fields of continental Europe, to the coffee plantations of Mexico, on slopes so steep the worker ties himself into the field, I have yet to see any system of hand-worked agriculture that holds any appeal socially, economically or in any other way to the American farmer. If the growing of sugar beets is to become more widespread on the thousands of acres of excellent land that never grew the crop before, then the amount of hand labor in relation to the value of the crop must be reduced.

By and large, I still think that this is a problem for the agricultural engineer; but maybe the agronomist can simplify his task if we re-examine our

own ideas on just how to grow a crop of beets.

In Michigan, we grow corn in anything from 28- to 42-inch rows; we grow field beans in anything from 28-inch rows to drilling them solid; we are a leading potato state with the crop in 30- or 40-inch rows or take your pick in between; we grow chicory in rows, mint in rows, soybeans in rows; and when it comes to sugar beets we think we need something still different from the multitude of widths we use for all the other crops. If that isn't enough to provide a 40-horse power headache for any agricultural engineer or maker of farm equipment, - then you tell one.

We adopted the growing of sugar beets from the hand-managed agriculture of Europe. Along with it we've accepted, possibly without careful examination, most of their cultural practices. With all due respect to the capability of European agriculturalists, conditions are different in North America from those prevailing in Europe, - for which we may be truly thankful.

Returning to row-widths, (and I use this old problem as illustrative rather than inclusive), I note from a California publication that it has been "fairly well demonstrated on the fertile peat soils of the Delta that more sugar to the acre can be secured through closer spacings than has been secured in the past by ordinary 20-inch rows and 12-inch spacing." Likewise, Professor W. Morley Davies of Great Britain reports that he ran an experiment, analyzed and cross-analyzed by the most approved statistical methods, which proved that there was a "significant increase to be gained by using 15- or 18-inch rows instead of 21 or 24." Significant, but is the application universally or even generally practical? Why, there isn't a single Belgian or Percheron on the farm of the Michigan State College that can walk down the middle of an 18-inch row of beets to pull a cultivator, - they walk on both rows of beets instead. And when we find we can't get a tractor down these narrow rows either, we tend further to complicate the problem by making paired rows, necessitating new adjustments in planter equipment, cultivator equipment, and harvest equipment. A grower recently told me he had to buy a new tractor to fit his new cultivator so he could grow beets in the most approved manner.

I'm not recommending that we launch on a program of wider rows for sugar beets, but I am suggesting we re-examine this and other agronomic problems in the light of what farmers in general have to do, rather than on the basis of what may have been deduced under special circumstances.

In 1939, we started a restudy of this problem as the result of a suggestion by Fred Bach, research agriculturalist for the Michigan Sugar Company. Bach, like myself and others, was advocating narrower rows in a section where beet growers also grow beans. Using results of old experiments and some agronomic inferences which the Farm Management boys pulled out of the grab bag in their cost account studies, we could prove that a beet grower could make $150 on every ten acres of beets by changing the cultivator from 28 inches for beans to 22 inches for beets. It worked out swell statistically. The only difficulty was that the farmers kept on growing beets in 28-inch rows.

Now maybe, on an experimental plot, we could get an extra ton and a half of beets in narrower rows; but the farmer, with his cultivator set for beans, and remembering the last time he'd knocked the hide off his thumb with a monkey wrench, said, "I'll let the beets go another week till I can give the beans one more run." - As a result he lost in practice, through failure to control weeds,

what we thought we had gained in theory. (I don't know what the standard error of that conclusion is. But as a practical consideration, the farmers still use 28-inch rows and there are about 17,000 degrees of freedom when it comes to determining what Michigan beet growers are going to do).

The general idea we followed in our 1939 trials was that if 28-inch rows are bad, how much worse are 38-inch rows? Maybe we can grow corn, beans, beets and potatoes all at the same row width, - so we tried it. Thirty-eight inch rows made no difference in 1939 with beans, improved our yield of corn, were essentially standard for potatoes, and with sugar beets proved no worse than 28-inch rows, and under the conditions of this experiment, fairly typical of the environment under which much of the Michigan crop was grown, both 28- and 38-inch rows outyielded 22-inch rows and were vastly superior in net dollars per acre.

No, we haven't settled the problem. But we've found an exception to the old rule, and, if the exception covers any appreciable range of conditions, one means of reducing labor and reducing expense for the average sugar beet grower is indicated.

Another agronomic problem which we in the eastern sugar beet area must consider, comes in connection with our breeding program. You of the west have already upset tradition, have your own varieties which meet your special needs, and grow your own seed. Our plant breeders in the east are also doing a good job. We have lines resistant to leaf spot, as you have. We have hybrids of superior vigor. We have a strain that maintains satisfactory sugar content on muck soils whereas others fall off. But we don't know what to do with them.

Must we follow the tedious methods of seed production used abroad? You in the west don't. You grow your seed after the American style of farming. Must we send our varieties to the southwest to be increased where winters are less destructive and seed yields large? That method, too, has its faults. Control of seed stocks is secondhand. Our best lines may succumb to curlytop, Curlytop resistant lines may be inferior in tonnage or sugar content when grown in Michigan or Ohio. For many reasons the home growing of seed is superior; so we are looking for feasible methods of growing seed, at least foundation seed, in the eastern area. We have found one locality where we can over-winter beets in the field, but the land is acid and infertile. Can we get satisfactory seed crops on that land by using lime, fertilizer and manure? We can get good seed crops from small stecklings. Is this method cheap enough? Is vernalization merely an interesting phenomenon or does it provide a practicable means of producing sugar beet seed in a single season? Twenty years ago they told us we wouldn't grow alfalfa seed profitably in Michigan. Maybe not, but in 1936, we grew more of it than any other state and we are essentially self supporting in this respect, to the tremendous advantage of our alfalfa growers.

We have a chicory industry in Michigan which, like the beet industry, was once entirely dependent on Europe for seed. According to European literature the chicory roots had to be over-wintered in storage, transplanted to an 18 x 36 inch spacing, the plants cut by hand and wrapped in cloth, 4 stalks per bundle, to avoid shattering, and the seed was priced to the American industry at anywhere from 30¢ to $1.50 a pound, depending on how friendly the European folks happened to be with each other.

Discarding European tradition, we sowed chicory in barley, overwintered

it in the ground, as the west does with beets, cut it with a binder and threshed it with a grain thresher, producing, at current war prices, something over $300 worth of seed an acre. We never expect the chicory industry again to be dependent on remote sources for seed. What has been done with alfalfa, and chicory, what the west has already done with sugar beets, the rest of the beet growing area can do too, when research tells us how.

Our worst disease in the east is leafspot (Cercospora beticola). Right now we are turning to dusting and spraying, defensive measures that add to the expense of producing sugar. Plant breeders can aid materially in reducing leafspot losses if agronomists provide a better means of growing the seed of their leafspot resistant varieties. Incidentally, breeding and cultural practices which lead to the development of strong healthy tops have much to do with the practicability of any harvesting machinery.

If, to control leaf diseases and provide strong tops, spraying or dusting are necessary, are there any additional benefits beyond disease control which might accrue if the right formula is used? In some of the spraying experiments there has been noted a seeming tendency for sugar content of the sprayed beets to be relatively higher even in the absence of disease on the untreated plants. Our horticulturalists tell us that Michigan's famed sour cherries become sweeter when the trees are sprayed with suitable copper formulae. Is there a comparable relationship between certain formulae and the sugar content of beets which goes beyond the effect in controlling leaf spot?

Another of our troublesome diseases caused by a complex of organisms, is damping off or black root. Pathologists tell us the trouble is intensified when beets are grown after alfalfa, sweet clover and other soil improving legumes. So we generally give lower value crops such as corn and beans the great advantage of following immediately after alfalfa in the rotation. Some of the best beet crops in the east follow alfalfa, while others when so planted succumb to disease. What is the difference? Would the proper time or manner of plowing, a different method of seed bed preparation, some soil treatment, a special fertilizer application or a resistant variety make the growing of beets on a plowed-under alfalfa sod more dependable? If it would, that too would reduce labor for each ton of beets and each pound of sugar.

What effect do different preceding crops have on beets, and beets on following crops? J. G. Lill of the United States Department of Agriculture is seeking an answer to this question with work in Ohio and Michigan. No one agronomist can study all the crops which are involved on an economic basis throughout the United States, but Lill's work has already shown sufficient differences in the growth of crops following oats, corn, soybeans and sugar beets to warrant much more study of this nature. Nothing has been found to support the fanciful claims occasionally heard that the sugar beet is a soil building crop. Likewise the response of other crops after beets has not reflected to the discredit of beets in comparison with other row crops and non-legumes. Such information should help the beet crops find its strongest place in the rotation, a problem which of itself demands constant consideration.

As a general statement of the sugar beet research problem, there are highly cogent reasons for devoting attention to that type of research which seeks new truths without immediate regard to their potential application. The plant breeder, for example, has only partially fulfilled his mission when he has developed a superior variety. He will have contributed much more to his

field, and eventually to agriculture, if in the process of breeding a superior variety he has learned one thing more about the processes of plant breeding or the manner in which the characters of his plants react. The agronomist who starts some of his questions with "Why?" rather than "Whether?" will eventually make a lasting contribution to his field.

However, most of the problems of the sugar beet industry are intensely practical problems which demand practical answers. Those whose research activities are sponsored by the sugar beet industry directly are perhaps unlikely to lose sight of that industry as a highly important economic enterprise; the rest of us cannot afford to do so.

That cloistered individual who works and sits and thinks as one apart may fulfill a mission in life. Should he ever become a member of society, I am certain we should be greatly bored in his company.

We have meetings such as this at which agronomists and sugar beet technologists discuss their various experimental projects. Is there a tendency to set up those projects to catch the interest of sugar beet technologists when the man who is vitally concerned with their solution is a farmer? Perhaps not. But whether or not the project is set up in that way I am quite certain that results are frequently reported so that they are intelligible only to that limited group. For certain types of work such reporting may be excusable.

However, picture the absorbing interest with which a beet grower who wants to know about fertilizer might peruse the following bed-time tale taken from a bulletin published for farmer use, "On the Jones farm all the fertilized plots outyielded the untreated plots, but the difference in one case was not significant and just barely significant in two other cases. In fact, the "F" value obtained for the placements is less than the "F" value at the 5% point."

The achievements in research which must be credited to sugar beet technologists have been fundamental to the well-being of this industry. Adequate support of research is absolutely vital to its future security. But research cannot stand apart. Research is diligent investigation to ascertain some truth or principle. To interpret is to explain, to understand and appreciate in the light of individual interest. Neither one alone, but research and interpretation together provide the motivation which leads to progress.

Section A. General Agronomy, Soils, Fertilizers, Production and By-Products - Chairman: H. D. Brown.

COMPARATIVE YIELDS OF EQUAL PLANT POPULATIONS OF SUGAR BEETS WITH DIFFERENT SPACING RELATIONS

By
G. W. Deming[1/]

In a preliminary report, F. G. Larmer[2/] gave the results obtained in California experiments with sugar beets hand thinned at 10-inch spacing as contrasted with doubles in hills spaced 20 inches apart. It was found that beets grown as doubles in hills 20 inches apart were comparable to beets grown singly 10 inches apart. In the California tests, increasing the spacing between two- and three-plant hills to 20 inches gave tonnage yields comparable to single-beet 10-inch spacing. Because of the significance of this finding, which centers interest on maintenance of the plant population while varying the pattern of arrangement, experiments were instituted to determine if varietal response was a factor in results to be obtained in such trials, and also to discover the magnitude of yield differences which might occur from departure from the customary singling method.

Materials and Methods

In 1938, eight varieties which were known to differ in yielding ability were selected for the comparison of results from 20-inch X 10-inch spacings and from similar plant populations in which the spacing was 20-inch x 20-inch. This test was planted near Ault in northern Colorado on land of high fertility. The previous crop was potatoes. The eight varieties were planted as a Latin square and the 64 variety plots were split for the following spacings: (1) single beets spaced 40 x 40 inches; (2) single beets spaced 20 X 10 inches; (3) two-plant hills spaced 20 X 20 inches. To accomplish this, the 8-row variety plots which were 90 feet long were divided into thirds, and the spacings as indicated were randomized on the 30-foot sub-plots. With the exception of a few plots, good to excellent stands were obtained. This test was harvested in late October in such a manner that yields could be computed on the basis of yields from normally-competitive beets as well as actual yields.

In 1939, three varieties were selected for the test: (1) a hybrid known to have high yielding ability, a relatively small crown, and not particularly heavy foliage; (2) a European brand said to have the ability to make maximum use of additional space (the performance of this variety did not bear out this expectation); and (3) a three-times inbred strain of very uniform top and root type and very low yielding ability.

The 1939 test was planted on the College Farm at Fort Collins, Colo., on land of high fertility. The preceding crop on this land was oats. The varieties were planted in six random blocks and these 18 variety plots were

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1/ Assistant agronomist, Bureau of Plant Industry, U. S. Department of Agriculture. Agronomic investigations are cooperative with the Colorado Agricultural Experiment Station.

2/ Effect of Spacing and Density of Stand on Hill Production of Sugar Beets. Proceedings, American Society of Sugar Beet Technologists, 1938:16.

split for the following spacings: (1) single beets spaced 40 X 40 inches; (2) single beets spaced 20 X 20 inches; (3) single beets spaced 20 X 10 inches; and (4) two-plant hills spaced 20 X 20 inches. Excellent stands were obtained for varieties 1 and 2; the stand of the inbred varied from poor to good on individual plots. The test was harvested in October in the same manner as the 1938 test and yields were calculated in the same way.

Results of the 1938 and 1939 Tests

Since in both 1938 and 1939 tests each of the varieties exhibited the same relative trend in yield and sucrose percentage in each of the spacings, discussion of varietal reaction to differences in spacing will be omitted. Data from all of the varieties in each test have been averaged in considering the effect of the spacings. The results from spacings as wide as 40 X 40 inches showed that yields were low. These data are omitted in this report.

The 1938 Test

The 1938 comparison reported is between approximately equal plant populations which in one case were spaced singly in a 20 X 10-inch pattern and in the other case were present as two-plant hills spaced 20 X 20 inches. Table 1 summarizes the 1938 test for the two spacings, 20 X 10 inch singles and 20 X 20 inch doubles.

Table 1.--Comparisons for acre-yields of roots and gross sugar, sucrose percentages, and for marketable roots per plot for plots with single beets spaced 20 X 10 inches and two beets per hill spaced 20 X 20 inches; 8 varieties, 8 times replicated, averaged. Data obtained on basis of normally-competitive beets per plot and as actual plot yields: Ault, Colo., 1938. (Results given as 64 plot averages)

Spacing	Normally-competitive beet basis			Actual-yield data				
	Acre yield			Acre yield			Roots harvested	
	Gross sugar	Roots	Sucrose[2]	Gross sugar	Roots	Sucrose	Total	Marketable[3]
	pounds	tons	percent	pounds	tons	percent		
20 X 10 inches (singles)	5,673	19.89	14.28	5,532	19.41	14.28	197	196
20 X 20 inches (doubles)	5,300	18.46	14.35	5,345	18.63	14.35	200	179
F value[1]	9.75*	14.76**	N.S.	4.70	6.97*	N.S.	N.S.	36.84**
Difference required for significance 19:1	282	.88	.58	205	.70	.58	5	7

1/ * F exceeds 5 percent point
**F " 1 percent "

2/ Sucrose determinations for each plot by using all normally-competitive beets from the plot to supply two composite samples.

3/ Weighing 0.4 pounds or more when topped at lowest leaf scar.

Discussion of 1938 Test

Since the difference in sucrose percentage in the beet for these two spacings falls far short of the level of statistical significance, the evidence from this test is that quality of the beets, as measured by this value, is approximately equal. The yield of roots from the 20 X 10 inch singles exceeds the yield from the 20 X 20 inch doubles by 1.43 tons and 0.78 tons for competitive beets and actual yields, respectively. These differences exceed the five percent point of probability. The advantage of the 20 X 10 inch singles is less clearly shown in gross sugar as calculated. On the normally-competitive beet basis, the difference was significant; but it was not significant on the actual-yield basis. Approximately equal numbers of beets were harvested from each of the spacing treatments, averaging 197 from the 20 x 10 inch singles and 200 from the 20 X 20 inch doubles. Since a perfect stand would have been 216 beets, it is evident that the average stands were excellent. When the number of beets of marketable size is considered, there is a considerable difference in favor of the 20 X 10 inch singles. Of the beets from the 20 X 20 inch doubles, 8.5 percent failed to reach a marketable size of 0.4 pound, which approximates a beet slightly in excess of 1 inch in diameter at the crown line.

The 1939 Test

The 1939 test differs from that of the previous year in that a plant population only half as great was also included, namely, single plants spaced 20 X 20 inches. The variety-space plots were 30 feet long, except in Randomized Block VI in which the plot length was 25 feet. Eight-row plots, with data taken from the six inner rows, were used with the 20-inch rows; 4-row plots were used with the 40 X 40 inch spacing, all beets harvested.

As previously stated, the interaction of varieties and spacings, if any, may be regarded as negligible. However, because of the wide differences in the yielding capacity of the varieties used in 1939, the results by varieties under the different conditions of spacings for stands, sucrose percentages, and actual yields are given in Table 2. Competitive-beet yields were of the same order and are omitted.

In the 1939 test, the yield of the inbred is undoubtedly significantly less than that of either of the normal varieties. Although the yield of the hybrid exceeds that of the commercial, the difference was not found large enough to be statistically significant. Since the yields of all three varieties exhibit the same general trends in the different spacings employed, the data for spacing effects in the following summary, Table 3, are given as averages of varieties. The 40 X 40 inch spacing results are omitted.

Discussion of Spacings, 1939 Test

The difference in sucrose percentages of the beets grown as singles in a 20 X 10 inch spacing pattern and those grown as doubles in a 20 X 20 inch pattern falls, as in 1938, within a range of chance occurrence. It is judged that the quality of the beets from these two spacings is not significantly different. While sucrose percentage of the roots from the 20 X 20 inch pattern, plants grown as singles, was not found to be significantly lower in this test, there appears to be a trend toward lower sucrose percentages when the plant population is reduced one-half.

Table 2.--Results from spacing test at Fort Collins, Colo., in 1939 for three varieties with four types of spacings, actual-yield basis. (Data given as 6-plot averages.)

Spacing pattern	Variety	Acre-yield of		Sucrose	Roots harvested per plot 1/	
		Gross sugar	Roots		Total	Marketable
		pounds	tons	percent		
20 X 10 inches, singles	Hybrid	6,653	21.40	15.55	200	191
do.	European brand	6,059	18.89	16.08	206	195
do.	Inbred	2,840	8.09	17.63	184	153
20 X 20 inches, doubles	Hybrid	5,569	17.89	15.59	206	177
do.	European brand	5,322	16.70	15.97	207	177
do.	Inbred	1,892	5.49	17.18	146	106
20 X 20 inches, singles	Hybrid	5,866	19.16	15.32	106	106
do.	European brand	5,240	16.71	15.73	104	103
do.	Inbred	1,742	5.23	16.74	81	74
40 X 40 inches, singles	Hybrid	2,334	9.11	12.82	(182)	(181)
do.	European brand	1,824	6.81	13.42	(184)	(183)
do.	Inbred	464	1.54	15.07	(152)	(138)

1/ Stands in the first three spacing patterns are given as 6-plot averages; full stands for the 20 X 10 inch pattern, singles, and the 20 X 20 inch, doubles, would require 216 beets and for the 20 X 20 inch, singles, 108 beets. The stands for the 40 X 40 inch spacings are given as totals for the six plots of each variety.

Table 3.--Effects of various spacing patterns on acre-yields of gross sugar, roots, on sucrose percentages, and on marketability of roots. The results are given on basis of normally-competitive beets harvested per plot, and also as actual plot yields. Calculated yields are based on roots weighing, when topped, not less than 0.4 pound: Fort Collins, Colo. 1939. (Data given as 18-plot averages.)

Spacing pattern	Based on normally-competitive beet basis			Based on actual plot yields			
	Acre-yield of			Acre-yield of		Roots harvested 2/	
	Gross sugar	Roots	Sucrose	Gross sugar	Roots	Total	Marketable
	pounds	tons	percent	pounds	tons		
20 X 10 inch, singles	5,416	16.82	16.42	5,184	16.12	203	193
20 X 20 inch, doubles	4,440	13.90	16.25	4,261	13.36	206	177
20 X 20 inch, singles	4,546	14.50	15.93	4,282	13.70	105	104
Difference required for significance 19:1	461	1.28	0.68	478	1.45	-	-
F value 1/	13.43**	14.46**	1.33	12.05**	10.67**	-	-
Excess of singles from 20 X 10 inch pattern over doubles, 20X20 inch pattern	976	2.92	0.17	923	2.76	-3	16

1/Values marked ** exceed the 1 percent point.

2/Because of lack of vigor, the inbred variety produced an abnormally large number of very small roots. The data for total and marketable roots harvested are based on the two other varieties in the test. Full stand for the first two spacing patterns listed would consist of 216 beets per plot, and for the third spacing pattern, 108 beets.

In this test, the acre-yield of gross sugar and roots of the 20 X 10 inch singles significantly exceeds the yield of the 20 X 20 inch, two-plant hills, both on the basis of normally-competitive beets taken from the plots and as actual plot yields. The differences are probably highly significant for this test, since, in every case, they considerably exceed the statistical requirement for significance for odds 19:1. In acre-yields of gross sugar and of roots, the 20 X 20 inch, two-plant hills, and the 20 X 20 inch, singles, did not differ significantly in this test. Stands of the hybrid variety and the commercial brand used in this test were excellent as shown by the total beets harvested, full stands, being 216, 216, and 108 beets, respectively, for the three spacing treatments in the order given in Table 3. The tendency for the number of unmarketable roots to increase when beets are grown two plants in a hill, as contrasted to one plant in a place, but spaced closer, was again shown.

Conclusions

Under the conditions of these tests, although plant populations for the two treatments were approximately equal, the yields from sugar beets spaced 20 X 10 inches and grown one plant in a place exceeded the yields from two-plant hills spaced 20 X 20 inches. It is to be noted that, whereas acre-yields of gross sugar in the 1938 test did not differ significantly between the two spacing patterns, significant differences were shown in 1939. These results suggest that conditions such as adequacy of water supply, soil fertility levels, or other factors, may have influence. In this connection, attention is called to the 1939 results in which with plant populations reduced by one-half in the spacing pattern, singles, 20 X 20 inches, the yields were essentially equal to those from the sugar beets grown in two-plant hills of the same spacing.

Summary

Results are given for variety-spacing tests conducted with sugar beets in 1938 and 1939 in northern Colorado. In 1938, 8 sugar-beet varieties were grown in a replicated test, on which the following spacing patterns were superimposed: 20 X 10 inch, singles; 20 X 20 inch, doubles; 40 X 40 inch, singles. In 1939, 3 varieties were used with the same spacing patterns as in 1938, with an additional one, 20 X 20 inch, singles. Significant differential responses among the varieties to spacing patterns were not found in either season. The number of unmarketable roots in both 1938 and 1939 was greater when the sugar beets were grown two plants in a hill than when spaced closer and grown as singles. The acre-yield of roots was significantly larger in both seasons with beets grown as singles with a 20 X 10 inch spacing than when grown as doubles with twice the spacing in the row. The acre-yields of gross sugar obtained with these spacing patterns were not significantly different in 1938 but were very significantly in favor of singles spaced 10 inches in the row in 1939. It is suggested that conditions of water supply, fertility levels, and other factors, may influence results from such trials.

POST-THINNING LOSSES AND THEIR CAUSES

By A. C. Maxson[1]

The causes and magnitude of post-thinning losses in stand were studied by Harry B. Shaw[2]. In summarizing his work Shaw makes this statement, -"those (losses) occurring between thinning and harvest range from 2.54 to 12.85 percent, with an average of 7.26 percent among the 18 plats from which these data are obtained."

Little attention seems to have been given this phase of sugar beet culture since Shaw did this work in Utah in 1910-11 and 12.

In discussing his studies Shaw does not mention diseases in connection with post-thinning losses.

Observations over a number of years indicate that losses in stand between thinning and harvest, in Great Western Sugar Company territories, have resulted in serious losses to the industry by reducing returns to both grower and processor.

If these losses are to be reduced or prevented their causes must be known. In order to secure this information studies were begun in 1938 designed to determine the nature of the causes and to learn the relative importance of each.

The plan followed in this study was as follows: Each fieldman was required to study at least one field. In this field 3 one hundred foot strips, each consisting of 3 rows, were staked immediately after thinning and the number of beets left in each row by the labor recorded.

The beets were recounted at stated periods during the entire season. The first count was made 3 days after thinning, the second 7 days after thinning, the third 2 weeks after the second, and all subsequent counts at 2 weeks periods.

Each time a count was made the number of beets lost was reported and the cause of the loss given.

Losses were found to be due to a wide range of causes including, diseases, insects, work animals, other animals, cultivating, exposure, hoeing, storms and other weather conditions, irrigation and unknown.

The heading "disease" covered black-root, Girdle scorf, Rhizoctonia root rot, Fusarium root rot, and other diseases. "Work animals" refers to losses caused by work animals in cultivating, ditching, spraying, etc. "Other animals" includes stray animals, rabbits, pheasants, gophers, etc. "Exposure" covers losses due to removing soil from around roots of small beets in thinning.

The 1938 and 1939 studies cover all Great Western factory districts. Eighty-three fields were studied in 1938. The total area was 2.85 acres

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1/ In Charge Experiment Station, Great Western Sugar Company.
2/ Bulletin No. 238, U.S.D.A., July 14, 1915.

carrying 75573 beets. In 1939 the study covered 78 fields, 2.61 acres and 67530 beets as left by the labor.

In 1938 a total of 4960 beets were lost and in 1939, 6539 were destroyed between thinning and harvest. These figures represent 6.45% and 9.68% loss, respectively, for the two years. The mean loss for the two years was 8.63%.

The losses for 1938 and 1939 are compared in the following tabulation:

Cause of Loss	Percent lost 1938	1939
Disease	3.14	3.38
Insects	0.40	0.85
Work animals	0.25	0.21
Other animals	0.48	0.50
Cultivator	0.70	0.79
Exposure	0.55	1.96
Hoeing	0.43	0.39
Storms	0.22	1.31
Irrigation	0.04	0.27
Unknown	0.24	0.02
Total	6.45	9.68

Insects were more active in 1939 than in 1938. Grasshoppers and blister beetles were responsible for most of the increased damage in 1939.

The loss from exposure was much higher in 1939 than in 1938. Differences in weather conditions during the thinning period are largely responsible for this increase.

May 1939 was 11.1° warmer than May 1938 and the precipitation was less than one-half that of May 1938. During May 1939 there were 6 periods of precipitation and 13 in May 1938. The month of June did not differ as widely the two years as May. June 1939 was slightly cooler and dryer than June 1938.

Storms and other weather conditions caused heavier losses in 1939 than in 1938. This loss was augmented by drouth and the general shortage of irrigation water in 1939.

The date of thinning had an influence upon the losses as is indicated by the following:

All cases thinned May 18 to 31, Loss 7.47%
" " " June 5 to 10, " 10.19%
" " " June 16 to 29, " 11.19%

The dates between May 31 and June 5 and June 10 and 16 were excluded so as to make a more clean cut separation between date groups.

The losses due to rabbits, pheasants, and insects were much higher in the late thinned beets than in those thinned early. Losses caused by Fusarium root rot were also higher in the late thinned fields.

There is a very marked decrease in Girdle scorf and black-root and a

slight decrease in Rhizoctonia in the late thinned fields as compared with those thinned early.

Disease was responsible for 47.97% of all losses in 1938 and 36.25% in 1939. The relation of the loss caused by each disease recorded to the total loss caused by disease in 1938 and 1939 is shown below:

Year	Disease				
	Rhizoctonia	Black-root	Girdle scorf	Fusarium	Unknown
1938	37.41	31.22	19.34	7.01	5.01
1939	34.19	27.43	26.83	10.69	0.86

The principal differences between the two years are found in an increase of Girdle scorf and Fusarium and a decrease in Rhizoctonia and black-root in 1939.

The several counts during the season divided the growing season into 11 periods. The heaviest daily loss took place during the first 3 periods, i.e., 3 days after thinning, the 4th to 7th days after thinning, and the 8th to 14th days after thinning. The total loss for the 21 days covered by these periods was 65.98% of the season's loss. The daily losses expressed in terms of the total loss for the season were 5.73, 5.51, and 1.9, respectively, for the 3 periods under consideration.

Losses due to insects, work animals, cultivating, exposure, hoeing, and irrigation are partly, at least, controllable. These constitute 36.7% of the total loss in 1938 and 46.1% in 1939.

Better care, more attention to the handling of tools and work animals and closer supervision of labor should materially reduce these post-thinning losses.

The effect of post-thinning losses is not proportionate to losses in number of beets. Much of the loss, especially that caused by disease, occurs so late in the season that the remaining beets have no opportunity to make up for this loss by increased growth as a result of the wider spacing the loss brings about. Therefore, these late season losses are more serious than those occurring earlier in the growing season.

A STUDY OF SUGAR BEET GROWTH AT JEROME, IDAHO

D. E. Smith[1]/

In an effort to determine the amount of growth made by sugar beets from week to week under conditions such as prevailed at Jerome, Idaho, during 1938 and 1939, representative growing beets were measured and a record of increase in circumference recorded. At the end of the growing season these beets were weighed.

To convert this weekly growth into pounds per acre, the following

1/Amalgamated Sugar Company

formula was used: - The total weight of a representative sample of beets is to their total circumference as the total growth in inches per acre (determined by knowing the approximate stand of beets) is to "X", or pounds of growth per acre.

After two seasons of measuring and weighing beets in test, as well as many others at random, it was found that on an average beets circumference at the soil level was 6.57 times their weight. A two pound beet would be near 13.1 inches around. A further example: - 60 average beets were measured and found to have gained .5 inches per beet in one week. Assuming that there were 21,000 beets on this acre and that all made an average gain, the total growth increase would be 10,500 inches. By using the above mentioned factor of 6.57, this would show a growth of 1,598 pounds on the acre within the week.

Figures on the large chart accompanying this paper were established through this method. For convenience they are presented here showing the year, the week, and the amount of growth in tons:

TONS GROWTH PER WEEK - PER ACRE

	1938	1939
July 21 to 27	—	.92
July 28 to Aug. 3	—	1.26
Aug. 4 to 10	—	.96
Aug. 11 to 17	1.96	.89
Aug. 18 to 24	1.70	.48
Aug. 25 to 31	1.44	.62
Sept. 1 to 7	.56	.45
Sept. 8 to 14	.82	.25
Sept. 15 to 21	.28	.13
Sept. 22 to 28	.46	.23
Sept. 29 to Oct. 5	.66	.37

It is interesting to note that in each year growth was most rapid during mid-summer, and gradually declined until fall. Also, that there was an "upturn" in growth at harvest each year. In 1938 this followed high temperature during the latter part of September, and in 1939 following recovery from a severe hail storm which occurred September 13th. It is also interesting to note that growth almost stopped immediately following the hail storm, but was recovering rapidly when harvested.

These beets were grown on the same land. In 1938 the land had been previously crowned out of 7 year old Alfalfa, fall plowed and 125 pounds of Triple Super-Phosphate drilled with the seed. The yield was 21.03 tons per acre. In 1939, ten tons of barnyard manure was applied, spring plowed and the crop irrigated up. The yield was 16.71 tons per acre.

During both growing seasons, moisture was kept as near an optimum condition as possible (never allowed to reach a permanent wilting point). Plant food appeared to have been ample during 1938, but may have been slightly lacking during the latter part of 1939. There was a mild infestation of curly top during 1938, but none in 1939.

The factors which affect plant growth were studied and the mean temperature together with stage of growth or maturity seemed to have most effect upon

the rapidity of growth - generally speaking, as the mean temperature declined, the amount of growth became less. The fluctuation of air temperature seemad to have a delayed effect upon growth, apparently because of the slowness of soil to "take in" or "give off" heat.

From these preliminary results, indications are that sugar beets make most growth during the warmer part of the season. That it is possible to establish a "factor" in a district to determine the growth in fields, to aid in estimating yields, to approximate the growth in test plots and similar work where factors affecting growth are being studied, and to record the growth of beets affected with varying degrees of curly top or other diseases.

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*INFLUENCE OF PLANTING DATE AND CULTURAL PRACTICES ON SUGAR BEET SEED PRODUCTION

Bion Tolman[1/]

Data from experimental plots in the St. George area indicate that the percentage of plants developing seedstalks, the rate of development of the seedstalks, the yield of seed per acre, and seed quality (including size of seed balls, percentage germination and weight per bushel) are influenced by planting date, fertility level, and cultural practices (including previous crop and time and method of seed-bed preparation).

These three factors (planting date, fertility level, and cultural practices) may act separately or in combination. The combined effect of any two factors may be additive or one may alter the effect of the other. For example, lack of phosphate and nitrogen may be accentuated by improper seed-bed preparation or the benefit of early planting may be lost as a result of poor cultural care or failure to supply needed fertilizer.

There is a definite relationship between planting date and proper fall growth, and the physiological processes of photo-thermal induction that takes place during the overwintering period. It appears to be desirable to make the fall growth as rapid as possible. No amount of care in the spring can compensate for the incomplete photo-thermal induction which may follow insufficient fall growth.

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* Read by "title."

1/Division of Sugar Plant Investigations, Bureau of Plant Industry, U.S.D.A.

MAIN CONSIDERATIONS FOLLOWED IN DEVELOPING COMMERCIAL BEET SEED GROWING IN THE SALT RIVER VALLEY OF ARIZONA

I. M. McDonald, A. A. Mast and R. C. Wood[1/]

Commercial beet seed production by the overwinter method in Arizona is now starting on the fifth season, this not including the 10 acre experimental planting harvested in 1935. During the past four seasons a total in excess of 22 million pounds of seed has been produced from 14,422 acres.

Drawing on the experience (1) gained in other seed producing areas and our own observations in the field, we have adopted basic practices that have consistently demonstrated better production and better quality of seed.

The necessary steps or stages leading up to successful seed production by the overwinter method are substantially the same regardless of the area of production. Stated briefly these are:

First Stage: Vigorous growth period in which good development of roots and tops is obtained.
Second Stage: Arrested growth approaching dormancy brought on by low temperatures.
Third Stage: Vigorous revival of growth with the return of warmer weather aided by those cultural practices making for rapid and sustained development through to practically the end of the fructification period.

The purpose of this paper is to discuss the steps followed in Arizona to achieve these objectives.

For the first stage the important considerations are:

1. Selection of Land.
2. Planting Dates.
3. Rate of Seeding.
4. Fertilizer Program.

Loam soils of good fertility, with a history of clean cultivation and good fertilizer practices, for obvious reasons, should be selected. Lettuce and melon land has always ranked at the top in beet seed performance. While yields on the basis of previous crops are pretty well in line, only the yields for the 1938-39 season are given in Table 1, for the reason that segregation for the 1937-38 crop and for crop years before that time are not as sharply defined, due for the most part to the over-lapping of previous crops for individual field units.

It should be pointed out at this time that none of the production figures given in this paper include yields for the U. S. curly-top varieties. This for the reason that much of this acreage has been placed outside the main beet seed growing areas, and that they permit a much greater latitude as to soils, fertility and cultural practices.

1/Manager and members of the "Western Seed Production Corporation," respectively.

Table 1.--Yields from Commercial Fields Segregated on Basis of Preceding Crop, 1938-39.

Preceding Crop	Number of Fields	Acres	Average Yield Per Acre
Spring Lettuce	4	365	2406 Pounds
Cantaloupes	4	186	2013 "
Fall Lettuce Followed by Small Grain	12	650	1962 "
Cotton Followed by Small Grain	6	403	1206 "
Cotton	5	131	879 "

The optimum dates for planting may vary from year to year for a given area. Comparison of yields from fields grouped according to periods over which plantings were made for the past two seasons, 1937-38 and 1938-39, show quite definitely that the planting in the Salt River Valley of Arizona should be completed by September 20th to 25th.

Dates Planted	Number of Fields	Total Acres	Average Yields Per Acre - Lbs. Seed
1937-38 Season			
Sept. 5 to 16	18	1005	1187
Sept. 16 to 21	17	1282	1346
Sept. 20 to Oct. 1	16	632	1010
Oct. 1 to 20	10	413	784
1938-39 Season			
Sept. 1 to 11	26	2307	2007
Sept. 11 to 21	18	940	1630
Sept. 21 to 30	8	283	1227

For the Season 1937-38 growth continued uninterrupted until almost the first of the year while for the 1938-39 crop year the fall season was rather short, with killing frosts coming before the middle of November. The two seasons included in this tabulation should well cover extremes in length of growing season that may be expected for the Salt River Valley.

Since the start of commercial beet-seed production in Arizona, the planting rate has been gradually reduced from 18 pounds to 14 pounds of seed per acre, maintaining throughout an average width between rows of 20 inches. Outstanding yields have been obtained from fields planted with less than 12 pounds per acre. For reasons that will be discussed later, the planting rate in Arizona cannot be safely reduced below that which will insure distribution of plants sufficient to give practically complete shading.

The fertilizer program at the start of the season should take into consideration the fertilizer requirement not only for the fall period but, insofar as this is possible, for the full crop year. It must be varied to meet the needs for the individual field.

The addition of phosphate to the beet seed crop through commercial

fertilizers in amounts of 50 pounds, or above, of available phosphoric acid is so well established that it might be termed routine. For most fields this is applied immediately before planting or as a side-dressing in the fall. Applications are made in the spring to those fields where the soil analysis shows a low available phosphorus level, less than 6 parts per million.

It has been demonstrated that adequate plant food, with especial reference to nitrogen, is an important factor in beet-seed production. (2) Our own observations, made in commercial fields, indicate that there is a very definite correlation between color of foliage during the vegetative period and yields. Fields maintaining good color stand out in seed performance. Distinct loss of color, leaves turning yellow through nitrogen deficiency, . . . leads up to yields well below the general average. That a nitrogen deficiency existed was determined by a comparison of analyses of roots taken from green and yellow areas within the same field, and this was further demonstrated by the marked responses in many fields following the application of nitrogenous fertilizers, especially those carrying readily available nitrogen.

Table 2.---Correlation Between Color of Foliage and Yields for Commercial Fields.

Group 1. Fields which maintained a dark green foliage color and good foliage growth throughout the season.
Group 2. Fields which showed an average color and growth, with parts of fields showing a slight yellowing and accompanying reduction in foliage during the winter months.
Group 3. Fields which showed considerable yellowing and reduction in foliage during the winter months.

Group	Number of Fields		Acre Yield of Seed - Lbs.	
	1938	1939	1938	1939
1	9	11	1581	2187
2	14	11	1247	1969
3	13	7	668	1241

While it is to be expected that fields of below average in fertility would fall in Group 3, this group also includes a good number of fields that started off with good promise, maintaining good color and growth into the late fall and early winter.

Time and method of application are important considerations in the commercial fertilizer program; application in time to prevent loss of color and retardation of growth, for reasons already given; placement of material for better economy and availability.

On the basis of observation made in commercial fields, our growers are turning to band placement in preference to the so-called broadcast method. The recent work of W. A. Frazier and W. T. McGeorge (3), based on tests upon fertilizer placement with lettuce in the Salt River Valley, indicate a superiority for the band placement method.

The two most important considerations for the winter, or dormant stage, are:

1. Moisture
2. Coverage

One works to the benefit of the other. By maintaining good shading and adequate moisture, lower mean temperatures and narrower daily fluctuations between night and day are obtained.

It should be added at this point that good shade holds back winter weeds and offers an environment less favorable to the beet leaf hopper, the latter always to be taken into account through the first two stages in Arizona.

Starting with the third and final stage, it has been well established that a good supply of plant food, with special reference to nitrogen, (4) and adequate moisture are essential to good seed performance; and this depends to a marked degree on early and uniform bolting with a high percentage of plants participating in the seed crop.

The irrigation frequency followed through the seed bearing period for the Salt River Valley varies somewhat depending upon the water retention property of the soil for the individual field. Overpeck (5) has pointed out that stopping irrigations too early or too wide a spread between irrigations may affect quantity of seed produced and very definitely influence quality.

A tabulation made for the 1938-39 season, segregating fields on basis of yields, shows that quality increases with the yield.

Table 3.—Segregation on Basis of Yields for Late Bolting Varieties, Showing Germination for Each Group - Season 1938-39.

Yields per Acre	Number of Fields	Percent Germination
Over 2050 Pounds	8	81.2
1700 to 2050 Pounds	9	77.4
Under 1700 Pounds	9	75.9

From the viewpoint of the commercial beet seed producer, yields are determined only after the completion of the harvesting and threshing of the crop; and the procedure followed in these operations has a definite bearing on final yields and quality. From the cooperative endeavor entered into by the Associated Beet Seed Producers at Denver, Colorado in January 1937, mechanical harvesting has progressed to the point that during the past season 1300 acres of beet seed were harvested with six machines in the Salt River Valley. For the larger operations mechanical harvesters are not only practical but have distinct advantages over the conventional hand methods employed. Provisions for the collection of shattered seed makes possible harvesting through the full 24-hour day and extends the harvesting season to a later stage of maturity. It deposits the stalks in continuous windrows, providing an ideal set-up for the traveling thresher. This type of thresher minimizes handling and thereby further reduces seed losses, which occur when material is collected by hand, placed on sleds and hauled to stationary machines.

With each succeeding crop we have come to a better appreciation of the importance of advancing the planting dates, and of maintaining a high level of soil nutrients and adequate moisture from the start to well toward the final stages of maturity for the crop. This and the greater mechanization of harvesting and threshing operations have done much toward stabilizing the sugar beet seed industry in the Salt River Valley of Arizona.

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THE STORAGE OF BEETS BETWEEN THE TIME OF HARVESTING AND SLICING IN SOUTHERN ALBERTA, CANADA

A. E. Palmer[1/]

The chief hazard encountered so far in the production of sugar beets in southern Alberta has been the possibility of injury of beets by freezing occurring before the beets were all harvested. The length of the harvest period, that is considered quite safe, that is between the time the beets are ready and the final freeze-up is approximately forty days, commencing about September 20. Freezing temperatures usually occur during this period and in one-third of the seasons since 1925, temperatures have been low enough to freeze the crowns of unharvested beets before the 15th of October. Beets remaining in the ground after the middle of October definitely run the risk of being frozen. This condition has made it necessary to develop methods of storing partially frozen beets. The shortness of the season has made it essential also to adopt practices of handling the crop that would interfere as little as possible with the speed of harvesting operations.

Loss from Small Field Piles:

Several years ago, it was the practice of inexperienced beet growers in the Alberta territory to pile their beets in small piles in the field and, if there was no frost expected at night, the beets were left uncovered until it was convenient to haul them to the loading station. An experiment was conducted at the Lethbridge Station in 1931 to determine the probable loss that might be incurred from this practice under our climatic conditions. Freshly dug and topped beets were weighed into piles containing 200 pounds each and the piles were left uncovered. Beets in these piles were weighed daily and the following losses in weight were recorded:

1/ Assistant Superintendent, Dominion Experimental Station, Lethbridge, Alberta, Canada.

Table 1.--Loss in Weight of Topped Beets Placed in 200 Pound, Uncovered Piles. Expressed in Percent of Original Weight

Day	Loss %	Day	Loss %
1st	6.00	8th	1.35
2nd	4.25	9th	1.65
3rd	2.50	10th	2.00
4th	2.15	11th	1.60
5th	3.75	12th	1.00
6th	3.00	13th	1.75
7th	2.00	Total loss for 13 day period	33.00

Loss in 13 days from similar piles covered with 4 inches of beet tops 22.72%

It will be noted in Table 1 that the loss in weight in the first 24 hours was 6% while in the next 24 hours the loss was 4.25%, or in 48 hours, 10.25% of the original weight of the beets had been lost. From that time until the end of the experiment, the daily losses were relatively uniform. By the end of 13 days the beets had decreased one-third in weight. When this excessive shrinkage was brought to the farmers' attention, it helped them to see the necessity of more care in handling their beets. Naturally the value of covering beets that could not be hauled was considered. Piles of beets similar to those left uncovered were covered with 4 inches of freshly cut beet tops. The loss from these piles was 22.7% in 13 days as compared with 33% from the uncovered piles. This reduction of about one-third in the loss by covering was important and undoubtedly justified the cost of covering, but the loss was still excessive. Naturally when the farmers came to a realization of these losses they were anxious to move their beets out of the field and deliver them at the loading station as rapidly as possible. This created a condition of the deliveries being more rapid than the loading stations could receive cars to handle them.

Piling at Loading Stations:

The sugar company attempted to meet the situation by placing the beets in large piles at the loading station as they wished to encourage the practice of removing the beets from the small field piles daily if possible to prevent loss in weight and especially to remove the hazard of having the beets frozen when freezing temperatures occurred. Table 2 contains the data of losses in weight occurring in loading station piles for 8 seasons, as compiled by the Canadian Sugar Factories Limited, who have kindly provided this information:

Table 2.--Loss in Weight of Beets in Piles at Loading Stations, Stored about 30 Days.

Year	Average Size of Piles	Height of Piles	Loss in Weight
	tons	feet	%
1926	24	8	6.1
1927	60	8	7.8
1928	214	8	9.6
1929	370	8	11.6
1930	1436	8	20.6
1931	372	8	10.8
1937	10385	18	10.5
1938	18177	18	4.6
Average			10.2

The average loss in weight for the 8 seasons, it will be noted, was 10.2% which was less than a third of the loss in uncovered small field piles but was still quite high. More important, however, than the average loss is the wide fluctuation in different seasons, which varies from 4.6% in 1938 to 20.6% in 1930. The small loss in 1938 and some other seasons indicates the possibility of safely storing beets if the season is satisfactory, while the very heavy loss in 1930 shows the results of attempting to store beets in large piles when some of the beets have been frozen. It may be thought that it would be possible to prevent putting any frozen beets into storage piles and this the receiving agents at the loading stations attempted to do. Their instructions were to place any loads that contained frozen beets directly into the cars to be shipped to the factory for immediate slicing or to refuse to accept them at all. However, it was found that regardless of the precaution taken, some frozen beets would slip into the piles and hot spots were the result. Similar but lighter losses were noted in the beets stored at the factory sheds as recorded in Table 3.

Table 3.--Loss of Weight in Beets Stored at the Factories. Average Storage period, 42 days.

Year	Loss in Weight	Year	Loss in Weight
	%		%
1925	14.1	1932	3.2
1926	4.1	1933	4.5
1927	7.9	1934	4.8
1928	6.0	1935	4.9
1929	6.4	1936	5.0
1930	19.9	1937	3.5
1931	5.7	1938	4.5
Average			6.7

Here again the excessive losses in 1930 are indicated.

Unfortunately, no satisfactory data are available of the sugar content and purity of the beets as they went into these piles.

Field Silo Piles for Storing Beets:

The experience with large piles stored at loading stations and at the factory was so disastrous in 1930 that the Canadian Sugar Factories Limited, who buy all of the beets produced in the Alberta territory, decided that some other method of storage must be followed and so mediumly-large covered piles, which have been called field silo piles, were constructed in the fields. After some experimentation, it was found that beets, even if partly frozen, could be kept fairly well in properly constructed piles.

Figure No. 1 shows a diagram of the field silo pile as it is now being used in the Alberta beet area:

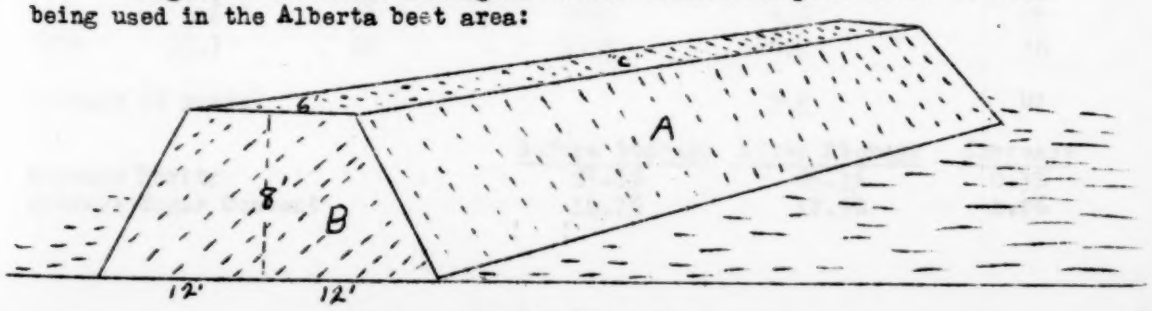

Fig. 1 Field Silo Pile

The dimension of the piles as now recommended are:

Unfrozen beets:	Width at base	20' to 30'	
	Width at top	6' to 10'	(top always flat)
	Height	7' to 9'	
Partly frozen beets:	Width at base	16'	
	Width at top	4'	
	Height	6'	

These piles are covered with beet tops and soil to reduce shrinkage and frost injury. It has been found that beets will heat if covered too much when first piled, so the sides (A) and ends (B) are protected with about 6 inches of dry tops and this covering sealed over with soil. The top (C) is always flat and is covered with about 4 inches of tops through which heat can escape. As the pile settles and cools more soil is added to the sides until the soil is about 10 inches thick at the base and 4 inches at the top. If partly frozen or badly frozen beets are being piled they are covered with tops only until excessive heating stops, then the sides are sealed with dirt as with unfrozen beets. One end of the pile is completed as soon as possible and covered immediately on the finished end, sides and top to check shrinkage and prevent freezing. Only the end on which the beets are being piled is left open and it is recommended to protect this face with canvas or other covering between loads and at night, especially if freezing temperatures or wind prevails. Incidentally, wind is one of the elements of Alberta's weather.

The storage of beets in these field piles placed the responsibility of assuming storage losses on the farmer, where previously this had been mainly borne by the manufacturer. Immediately the beet growers requested adjustments to be made in their contract to reimburse them for the losses sustained in storage and for the extra labor involved. Therefore, it became necessary to secure some information regarding losses occurring in this type of pile, so all of the beets produced at the Dominion Experimental Station at Lethbridge, Alberta, were weighed into a silo pile with careful attention being given to proper taring and the beets were weighed out when moved to the factory, with the same care being taken in securing tares. Purity and sugar content tests were made of the beets both when they went into the piles and when they were removed. The losses in weight each year and the average changes in purity and sugar content for the 8 years are shown in Table 4:

Table 4.—Field Silo Storage Piles

Year	Loss in Weight	Days Stored	Year	Loss in Weight	Days Stored
	%			%	
1931	6.2	29	1935	6.3	48
1932	10.3	34	1936	10.7	61
1933	5.6	54	1937	3.6	27
1934	10.7	88	1938	6.2	36
Average (8 years)				7.5	47

	Before Storage	After Storage	Increase
Average Purity	85.0%	85.3%	0.3%
Average Sugar Content	16.7%	17.9%	1.2%

It will be noted in Table 4 that the average shrinkage for a mean storage period of 47 days was 7.5% of the original weight. It appears that the length of time that the beets were in storage influenced to some extent the amount of loss incurred but the loss in weight was not entirely in proportion to the length of time that the beets were held in storage. The condition of the beets when placed in the piles, especially the presence of any frosted beets, influenced the losses. Other than this, the amount of wind seemed to be an important factor and indicates the necessity of applying sufficient cover to prevent the beets from being dried by excessive air movement through the pile. Excessive covering could not be used, however, or heating developed.

On the whole, the beets coming out of the piles were in good condition for slicing as indicated by the purity tests made. This is in agreement with the generally observed condition at the factory of the beets working up well through that period of the run when deliveries were being received from the siloed piles.

The data secured on the sugar content indicate a slight, although not a statistically significant, increase in percentage of sugar present when the beets were removed as compared with the sugar content when the beets were placed in the pile, indicating that there may have been less loss of sucrose than of total weight. This too is in agreement with factory experience.

The value of the field silo storage pile as a means of caring for beets during the period between the harvest and slicing has been considered carefully in the Alberta district. Some of the advantages are that it is quite convenient for the farmers to move their beets from the field on to these piles as the beets are topped and this definitely encourages them to pile the beets immediately. A number have developed the practice of topping on to low flat racks and hauling directly to the silo piles while others fork the beets on to wagons or trucks and haul them to the piles. It appears that the loss in storage with fresh beets tends to be lighter than in the large unprotected station piles and the risk from spoilage where frozen beets must be handled is decidedly less in properly constructed field silo piles than in the large storage piles at the loading stations or at the factory sheds.

There is an indication also that in the Alberta territory the general run of beets can be kept with greater safety for longer periods in the field piles than they can in the large storage piles. This suggests the possibility of lengthening the period the factories could operate by using field silo storage.

The objections of the farmers to the field silo pile are principally two: first, they do not like to take their beets out of the silo piles and deliver them during the cold winter weather but much prefer to clear up the entire operation and have the beets off their hands at the end of harvest and, second, the beets must be unloaded into the piles and loaded again. The use of nets or other equipment for unloading is reducing the work of this double handling. There also is a small loss of beet tops used in covering the pile as it is difficult to salvage all of the tops when removing the dirt from the piles.

One difficulty encountered by the manufacturer is that with a contract based on the growers receiving a percentage of the total revenue obtained from

the manufactured sugar, the question of placing the cost involved in field storage and reimbursement for loss in storage requires one more item for reckoning. The practice that has developed in Alberta is that the farmers are paid 65 cents per ton extra for beets that are properly stored in silo piles and 50 cents per ton, or total rejection, for improperly siloed beets. This amount of 65 cents is calculated on the following basis:

Loss to grower due to shrinkage	$0.25
Cost of extra labor	0.40
Total payment	$0.65

In this arrangement the manufacturer assumes the payment of 40 cents for extra labor while the 25 cents paid for shrinkage is charged one half to the manufacturer and one half to all the growers, sufficient being deducted from the price paid for all beets to meet the growers' share of this payment. The division of the 25 cents between the manufacturer and growers is based on the assumption that there is no decrease in the amount of sucrose during the silo period but that the shrinkage is all of non-sucrose. As the payment for beets in this territory is on a pool basis and on a fifty-fifty arrangement between the grower and manufacturer, it is assumed that each benefits equally by the higher sugar content of beets delivered from silo piles.

From 10% to 41% of the Alberta beet crop has been siloed each year for the last 10 years. The actual amount siloed each year depends on the weather during harvest. The practice now followed in handling the crop is for the sugar company to receive all of the fresh, undamaged beets after they are ready to dig, as fast as the farmers can make delivery but all beets damaged by frost or exposure that cannot be immediately sliced must be placed in silo piles until they can be used at the factory.

Where there is no special reason for siloing beets, the farmer may receive the siloing payment for any beets siloed only up to a maximum of 10% of his crop. This arrangement seems to meet the situation and to be satisfactory both to the growers and manufacturers. About the only phase that is still unsettled is the payment that should be allowed for field siloing. To adjust this equitably may require more information as to shrinkage, possible loss of refinable sucrose and especially the extra cost involved in siloing. As to the value of field siloing, there is full agreement that under Alberta conditions the field silo pile is essential and that it has done more to insure the satisfactory harvesting of the crop than has any other development.

A PRELIMINARY REPORT ON THE EFFECT OF TEMPERATURE AND BEET CONDITIONS ON RESPIRATION AND LOSS OF SUGAR FROM BEETS IN STORAGE*

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E. M. Mervine, Bureau of Agricultural Chemistry and Engineering,
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and
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Facilities and personnel for the laboratory studies were contributed by the Botany and Plant Pathology Section of the Colorado Experiment Station.

Analyses for sugar content were made by the laboratory staff at the Fort Collins field station of the Division of Sugar Plant Investigations, Bureau of Plant Industry, U.S.D.A.

Introduction

Mechanical methods of thinning and harvesting sugar beets, as contrasted with the regular hand methods may result in more beets of smaller size, in dirtier beets (that is, beets with more leaves and petioles clinging to them), and in a larger number of mechanically cut and bruised beets. In the experiments discussed in this paper, an attempt was made to determine the differences in sugar loss and keeping qualities of beets during storage which may be attributed to these conditions.

Although no significant differences were found in the respiration rates of different sizes and conditions of beets in these experiments, it cannot be safely assumed that no differences actually exist. It is possible that under more severe conditions of test or if more samples were used, significant differences would have been obtained.

Respiration is a biological-chemical process accompanied by the evolution of carbon dioxide and the liberation of energy. The most frequent type of respiration, involving the absorption of atmospheric oxygen, is termed aerobic respiration. Anaerobic respiration occurs in the absence of a supply of atmospheric oxygen. Two of the end products in either case are carbon dioxide and energy in the form of heat.

It is commonly assumed that hexose sugars ($C_6H_{12}O_6$) are the substances consumed during respiration. Sucrose ($C_{12}H_{22}O_{11}$) is the principal sugar in sugar beets but sucrose is hydrolyzed by the enzyme invertase or sucrase yielding a molecule each of glucose and fructose, both of which are hexose sugars. With theaerobic breakdown of hexose, therefore, the carbon dioxide produced may be collected, measured and calculated in terms of sucrose, which is the potential source of respirable material. Thus the rate at which carbon dioxide is liberated becomes an index of the rate of sugar loss. If carbon dioxide liberation is at a uniform rate, it is probably due chiefly to aerobic respiration. If, however, the rate of liberation suddenly and rapidly increases, it is doubtless due to fermentation or rotting caused by the invasion of bacteria or fungi as well as to the respiration of the organisms. Certain

complications arise in this connection which will be discussed later.

Several factors operate to control the rate of respiration, one of which is temperature. Respiration rates are uniformly accelerated by rising temperatures over a limited range. Relatively high temperatures favor bacterial and fungal activity which induce rotting and fermentation. Owing to these influences, marked increase in the respiration rate was observed at temperatures of 75°F. and over.

The first practical step in the reduction of storage losses, therefore, appears to be that of keeping the temperature low. By doing so, natural respiration is kept low and there is less rotting. Two conditions affect pile temperature--weather and the heat given off by respiration. Both of these are affected by the circulation of air through the pile. When a high wind occurs, the pile temperature responds quickly to outside temperature due to increased circulation. On the other hand, the effect of outside temperature on pile temperature may be slight if there is little circulation. In this case, respiration probably liberates sufficient heat, even at low temperatures, to raise the pile temperature a measurable amount during a twenty-four hour period. Then, as the temperature rises, the respiration rate increases. When a sufficiently high temperature is attained, rotting starts, respiration increases, and a "hot spot" is the result. In order to reduce sugar loss, therefore, it appears that the pile should be well ventilated and be kept as cool as possible without freezing.

The experiments discussed herein are divided into two main groups: (I) Storage Pile Experiments; and (II) Laboratory Experiments.

I. Storage Pile Experiments

A. Purpose

There were three things to be observed in this division of the experiments: The first observation was the relative sugar loss and keeping qualities of four types of beets placed in the storage pile. The second was the temperature fluctuations in the storage pile at various points, leading to information regarding the rate of air movement in the pile, the correlation between external conditions and pile temperature, and the effect on pile temperature of size and condition of beets. The third was to determine the carbon dioxide content of the atmosphere in the pile, to find out if carbon dioxide accumulated in the atmosphere surrounding the four different types of beets.

B. Apparatus.

The apparatus consisted of twenty wood-and-wire-mesh cages, each having a capacity for approximately one ton of beets; thirty-six thermocouples and leads connected with a potentiometer; and ten one-eighth-inch metal pipes, thirty feet long, equipped with guards at one end, to sample the atmosphere for carbon dioxide in ten of the cages.

C. Procedure

Four classes of beets were arbitrarily established:

(1) Standard, comprising 90 percent (by number) over 3" in diameter and 10 percent between 3" and 1¾".

(2) Small, consisting of 50 percent over 3" and 50 percent between 3" and 1¾".

(3) Dirty, composed of standard sized beets 25 percent of which were topped high. Each high-topped beet was accompanied by one leaf.

(4) Bruised - Standard sized beets which were dropped 30" onto a corrugated iron surface.

Twenty samples - five each of the four different classes - were counted and weighed in and out of storage. They were placed in cages and set at ramdon in five replicates in the pile. Representative sugar and dry weight samples were taken of each type before and after storage in order that the quantity of sugar lost during the storage period might be estimated on the dry weight basis. This is necessary to prevent confusion of moisture loss with sugar loss.

One thermocouple was placed in each of the twenty samples and sixteen were placed in a pile cross section. (See Fig. 1, p. 55.) The temperatures of all thermocouples were taken daily. In addition the cross section temperatures were taken hourly for one twenty-four hour period and one forty-eight hour period.

A record of the outside temperature over the period of storage was obtained from the recording thermometer of the Great Western Sugar Company factory near the pile.

A wind record over the storage period was obtained from the Meteorological Laboratory of the Colorado Agricultural Experiment Station located on the Colorado State College campus about two miles from the pile.

The pipes for carbon dioxide collection led from the first ten cages to the outside of the pile. From these, carbon dioxide analyses were made twice during the storage period.

D. Results.

Among the four classes of beets studied, no significant differences were found in sugar losses or in shrinkage. The shrinkage averaged 7.9 percent for the storage period of 47 days.

The sugar loss of the samples in the storage pile was determined by analyzing representative samples of beets at the beginning and at the end of the storage period. The errors involved in determining the sugar loss are such that an accurate measure of sugar loss cannot be made, but within the limits of the statistically standard error the sugar loss was not greater than the .06 pound per ton of beets per day of storage as determined from the respiration curves.

The temperature results are plotted on the graphs of Figures 2 and 3.

Circulation of air through the pile apparently did not cause the temperature to fluctuate with the change in outside temperature, unless the temperature remained at the changed level for an extended time or unless the wind was blowing.

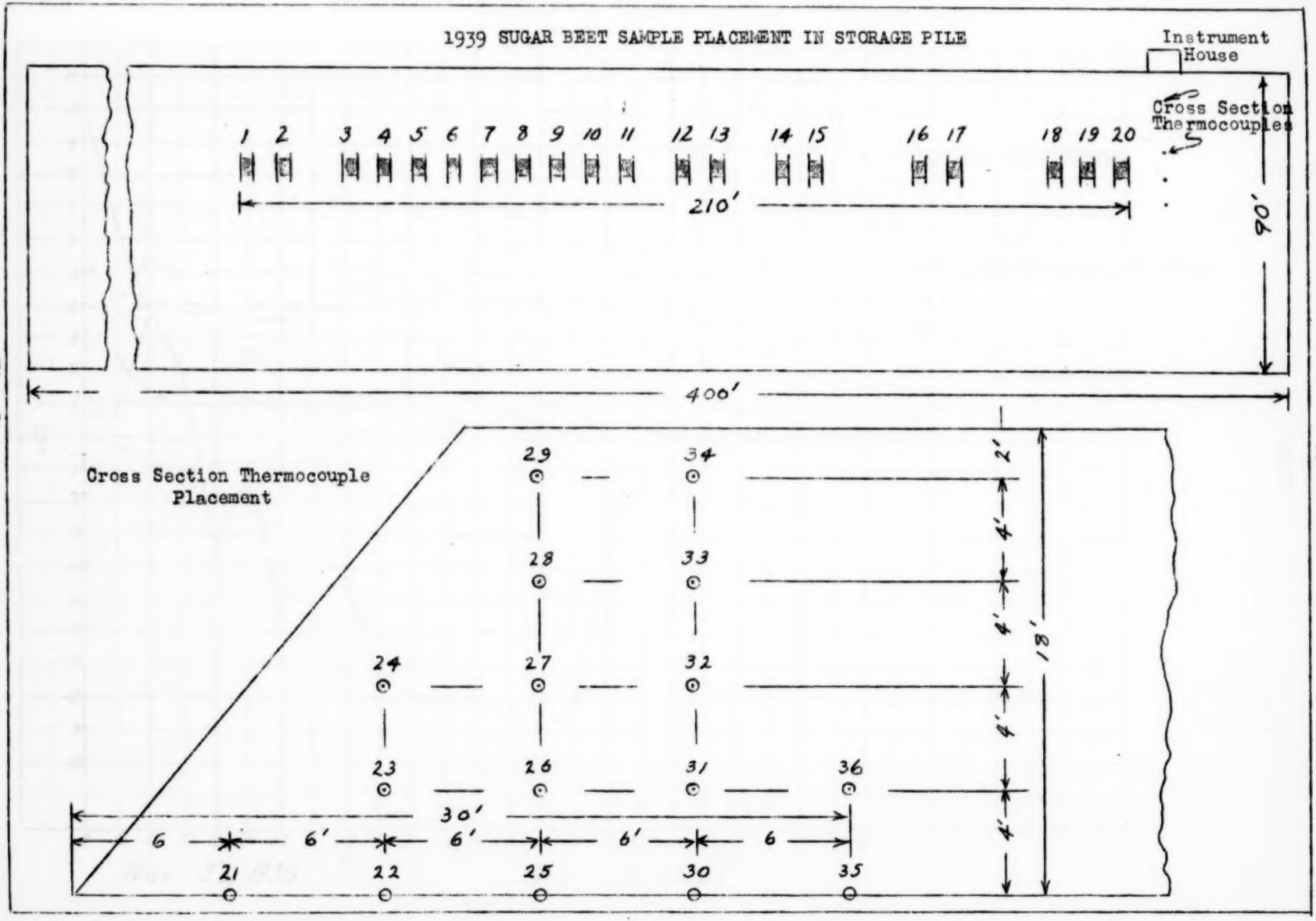
1939 SUGAR BEET SAMPLE PLACEMENT IN STORAGE PILE
Instrument House
Cross Section Thermocouples
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
210'
70'
400'
Cross Section Thermocouple Placement
29 34
28 33
24 27 32
23 26 31 36
21 22 25 30 35
2' 4' 4' 4' 4'
18'
30'
6 6' 6' 6' 6

Fig. 1

THERMOCOUPLE TEMPERATURES IN CROSS SECTION OF STORAGE PILE, 1939
(without switch)

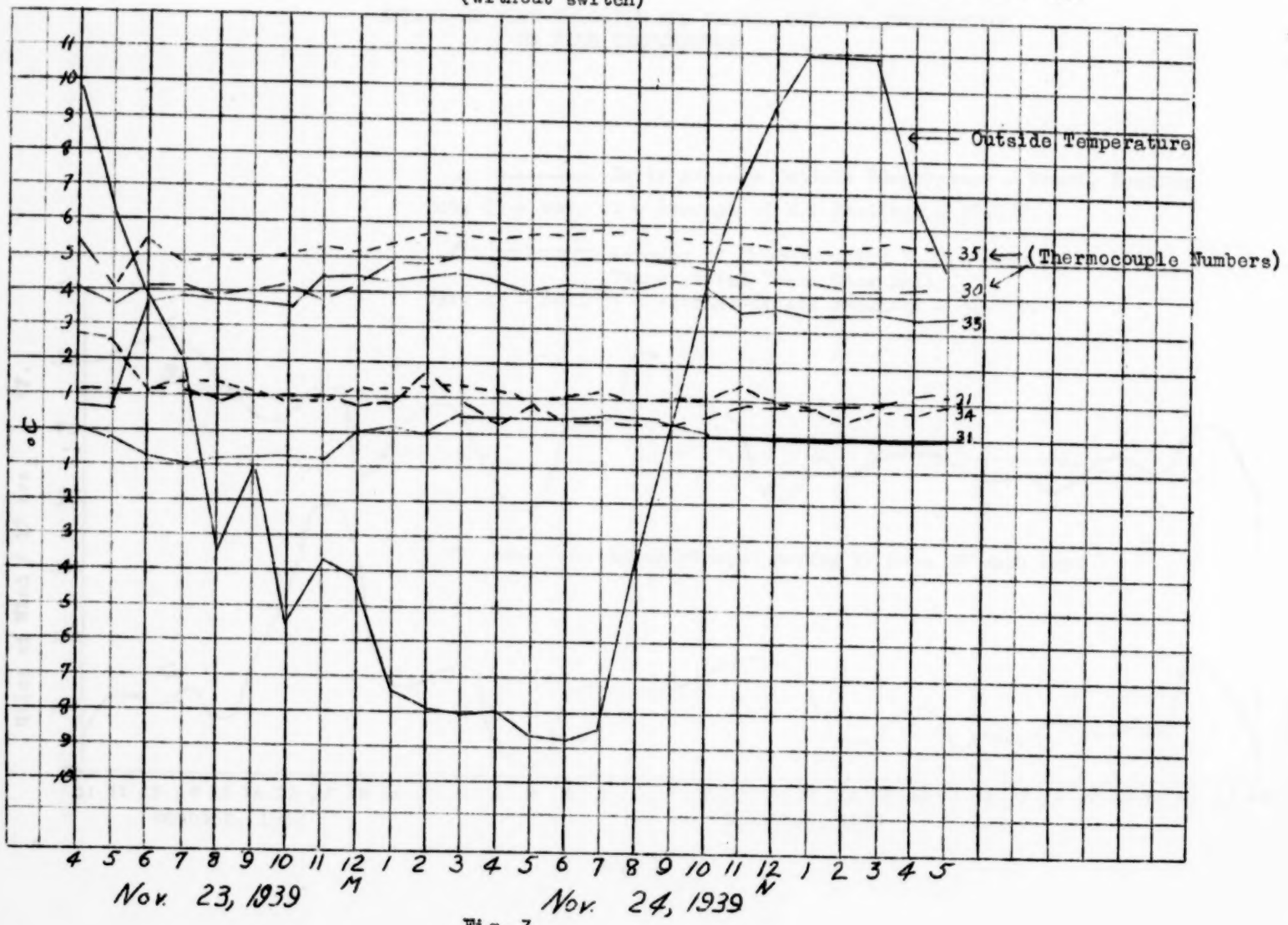

Fig. 3.

EFFECT OF WIND VELOCITY AND VERAGE OUTSIDE TEMPERATURE
ON PILE TEMPERATURE

A. ——— Daily Average Outside Temperature - Hourly Readings.
Oct. 23 - Nov. 21 - Average of all Readings - 39.0°F.

B ——— Average of Thermocouples 1-20 - Reading of Temperatures Taken Once Daily.
Oct. 23 - Nov. 24 - Average of All Readings - 37.7°F.

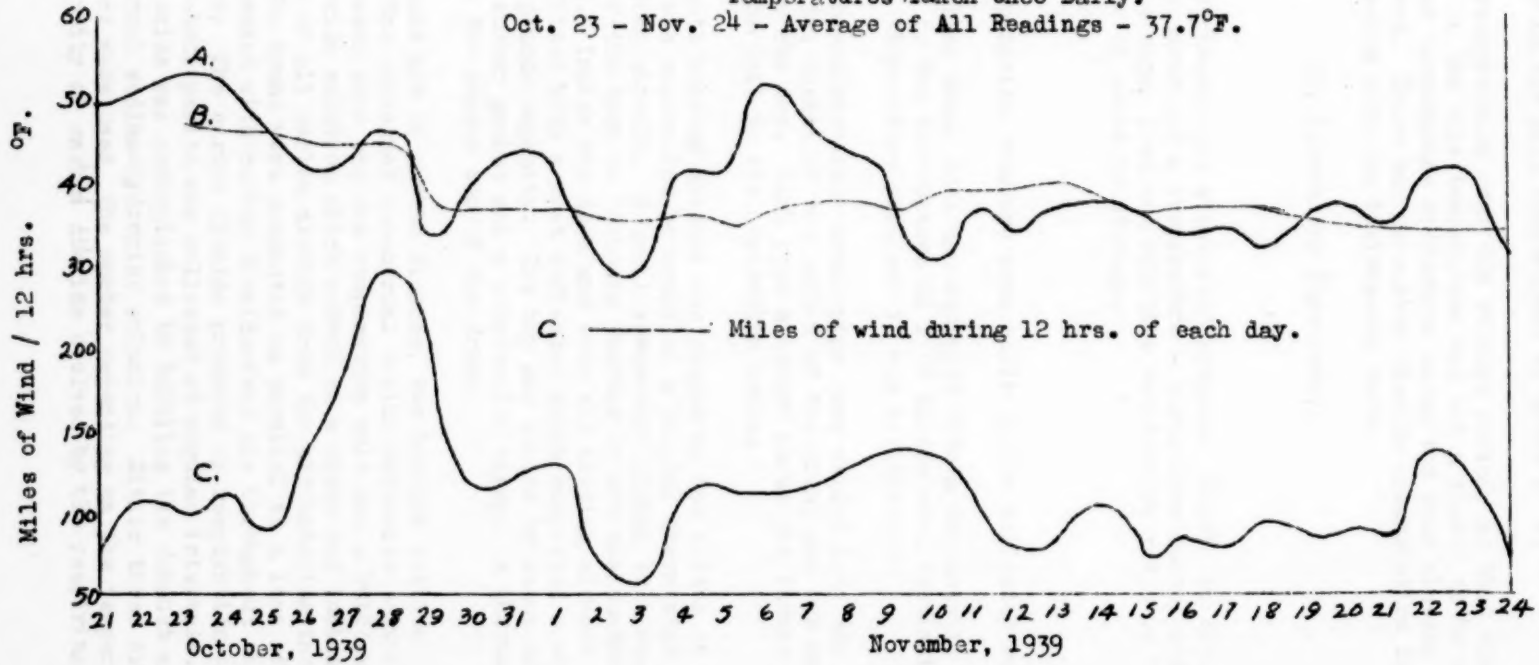

Fig. 4

Referring to Fig. 3, it appears that outside temperature fluctuations when accompanied by high wind velocities had rapid effect on pile temperatures. On the 28th and 29th of October an outside temperature drop accompanied by wind resulted in a drop in the pile temperature of about 8° F.

There was no precipitation over the storage period, so that the effect of rain or snow on the pile temperature was not a factor to be considered. No significant temperature difference among the four classes of beet samples was observed. There was no carbon dioxide accumulation in the pile that could be detected with the instruments used.

II. Laboratory Experiments

A. Purpose.

This set of experiments had a two-fold purpose: First, to obtain a temperature-respiration curve and a temperature - sugar-loss curve, and second, to determine the sugar loss and relative respiration rates as influenced by different types of beets in storage.

B. Apparatus.

Thirty-four respiration chambers were built in the following manner:

A fifty-five gallon metal drum was equipped with a demountable top. It was covered with one or two thicknesses of 1/2" balsam wool insulation, the amount depending on the temperature gradient it was to maintain.

Two lengths of one-eighth-inch metal pipe were welded into the top, one reaching to within two inches of the bottom of the drum, and one extending about three inches below the top. Each pipe extended about six inches above the top for attaching the unit to the aspiration train.

A one hundred-watt heating element was placed in the bottom of the drum. The temperature was controlled by means of a bimetal thermostat acting as a switch in the heating circuit. A small seven-watt signal bulb was placed on the outside of the drum to indicate whether or not the heating element was functioning. Inside the drum and over the heating element was placed a tripod stand fitted with a heat deflector which supported a wire basket of about thirty pounds capacity. The top was sealed by means of a glycerin soaked sponge rubber gasket and a compression clamp. A thermometer was placed in a hole in the center top of the drum.

To free the intake air of carbon dioxide, two bubbler bottles ordinarily were used. One contained two-normal sodium hydroxide solution. Connected in series between this and the respiration unit was a bubbler bottle containing barium hydroxide solution which served as a check and indicator to insure complete removal of all carbon dioxide from the air entering the respiration chamber. The drums were connected in parallel to a line of reduced pressure and aerated with carbon dioxide-free air throughout the period of the experiment. The carbon dioxide produced by respiration of the beets for a twenty-four-hour period was collected at regular intervals. Absorption of carbon dioxide was accomplished by bubbling the exhaust air through standard one-normal sodium-hydroxide solution. Either three or four sodium hydroxide bubblers were used, the number depending on the temperature of the sample. The quantity of carbon dioxide evolved by the respiring sample

was determined by differential titration. Test solutions of standard barium hydroxide were used in all cases to insure complete absorption. Screw clamps were used to adjust the aeration to an approximate uniform rate so that the air volume of the units was changed once in about every six hours.

C. Procedure.

For the laboratory studies, the beets were washed free of soil and allowed to dry until the surface moisture was completely evaporated. The samples were weighed to check within ± 0.20 pound and, after counting the number of beets, were placed in the baskets in the drums.

A total of thirty-four respiration units were set up and experiments were performed on the following beet samples:

Standard beets (as defined previously) held at 35°, 45°, 55°, 65°, 75°, 85°, 95° F.; small bruised and dirty beets at 45° F.; small bruised and dirty beets at 65°F.; low topped beets, standard beets treated and bruised beets treated at 65°F. The treatment consisted of dipping in "Dowwax." Temperature control was facilitated by holding the lower temperature units in a cold storage room, while the higher ones were set up in the basement of one of the college buildings.

These samples were all run in duplicate except the standard beets at 65° for which four samples were used. Carbon dioxide samples were collected from the lots held at 75°, 85° and 95° twice weekly and from all the others once a week.

At the beginning of the experiment representative samples of unstored beets were analyzed for sugar content and calculations were made on the dry weight basis. At the end of the storage period sugar analyses were again made on the stored beets and the loss in pounds of sugar per pound of dry matter was calculated. For obvious reasons this was necessary since the loss in fresh weight during storage is due largely to loss in moisture content.

Relative respiration rates by the measurement of carbon dioxide produced were determined, and the calculations were made to grams of carbon dioxide per pound of fresh material per day.

D. Results.

Theoretical sugar loss, as sucrose, was calculated from the equation $C_{12}H_{22}O_{11} + 12O_2 \longrightarrow 12\ CO_2 + 11H_2$. Hence from the value of carbon dioxide obtained the quantity of sugar used could be determined by a simple calculation, if we assume that all the carbon dioxide was liberated in aerobic respiration. It is probable, however, that considerable anaerobic respiration or fermentation took place, in which case the breakdown of sucrose might yield moderate quantities of carbon dioxide together with alcohol, organic acids, etc., instead of carbon dioxide and water. The probable reaction is as follows:

$$C_{12}H_{22}O_{11} \xrightarrow{\text{Hydrolysis}} \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(fructose)}}{C_6H_{12}O_6}$$

$$2C_6H_{12}O_6 \longrightarrow 4C_2H_5OH + 4CO_2$$

In the destruction of one mol of sucrose (342 gms) by aerobic respiration, 12 mols (528 gms.) of carbon dioxide would be produced, while by anaerobic respiration one mol of sucrose would yield only four mols of carbon dioxide or 176 grams. Consequently, by assuming that all the carbon dioxide produced resulted from aerobic respiration only, the apparent sugar loss would be about 33 per cent of the value obtained if all the carbon dioxide resulted from anaerobic respiration alone. It should be kept in mind that the alcohol, etc., produced in anaerobic respiration probably would not be oxidized to carbon dioxide and water.

Since the amount of oxygen consumed in these experiments was not measured, no respiratory quotients could be calculated to determine the type of respiration in progress. The carbon dioxide which was measured represents that produced by both aerobic and anaerobic respiration and no attempt was made to evaluate each one separately. It is clear, therefore, that the sugar loss, if calculated on the basis of the carbon dioxide produced by aerobic respiration, would necessarily be something less than the actual loss as measured by sugar analysis. This was especially true at the higher temperature where anaerobic respiration, fermentation and rotting were doubtless more rapid.

The results of the respiration studies are shown in Tables 1 and 2 and Figs. 4 and 5. The data showed no significant difference in the respiration rate of the various types of beets used. There was, however, a close correlation between temperature and respiration as shown by the standard beets.

The data in Table 1 show the effect of temperature on the respiration rate of standard beets (1) in terms of carbon dioxide (grams) per pound fresh weight per 24 hours, (2) the loss of sugar (pounds per ton fresh weight) per 24 hours as calculated from the carbon dioxide produced, and (3) the loss of sugar as determined by analyses. The data given in this table are presented graphically in Figure 4.

There was a gradual increase in the respiration rate with increasing temperature up to 18.5°C. (65°F.), as shown by the carbon dioxide values, (A, Fig. 4). As the temperature increased above 18.5°C., the rate of carbon dioxide production was rapidly accelerated. This rapid increase at the higher temperatures suggests invasion by fungi, resulting in decomposition.

The values of the sugar lost in respiration and rotting at the higher temperatures, if calculated from the carbon dioxide produced, are misleading since the loss of sugar is actually greater than seems apparent from the carbon dioxide values. This is clearly shown by the curves in Fig. 4. At the lower temperatures the sugar losses, as calculated from carbon dioxide produced and as determined by analyses, have a common difference but that difference increases as the temperature rises. Hence the differences between the curves probably represent anaerobic respiration.

Rot caused by fungi started at the highest temperature (35°C.) within twelve days after the start of the experiment. At 29.5°C. rotting and fungal action was delayed 14 days and at 24°C. this was delayed still another 14 days.

Tests for carbon dioxide from the samples in the large pile failed to show accumulation of the gas, which suggests unexpectedly rapid natural aeration.

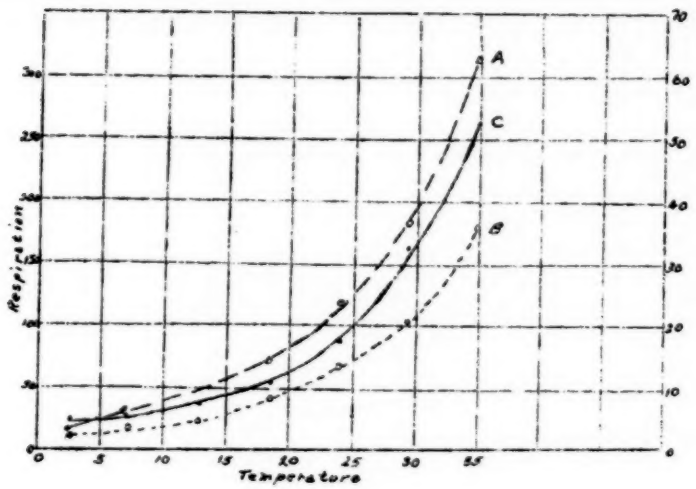

Fig. 4.

Effect of Temperature (Degrees C.) on Respiration Rate of Sugar Beets in Storage. (Ave. for 47 days).

A. Respiration expressed in grams of carbon dioxide liberated per pound of fresh material per 24 hours. Values shown at right of figure.

B. Respiration calculated from carbon dioxide liberated in terms of pounds of sugar lost per ton of beets per 24 hours. Values shown at left of figure.

C. Respiration in pounds of sugar lost per ton of beets per 24 hours. Values shown at left of figure.

Table 1.--Effect of Temperature on Respiration Rate of Beets in Storage*. (Average for 47 days.)

Temperature	Carbon Dioxide(1)	Sugar loss calculated from Carbon dioxide (2)	Sugar loss by analysis (3)
2-3°C.(35°F.)	0.039	0.113	0.230
7°C. (45°F.)	.065	.166	.269
12.8°C.(55°F.)	.078	.224	.384
18.5°C.(65°F.)	.142	.405	.514
24°C.(75°F.)	.235	.669	.882
29.5°C.(85°F.)	.361	1.032	1.610
35°C. (95°F.)	.625	1.783	2.610

(1) Grams carbon dioxide liberated per pound of beets (fresh weight) per 24 hours. (See curve A of Fig. 4).

(2) Sugar loss calculated from carbon dioxide in pounds of sugar per ton of beets (fresh weight) per 24 hours. (See curve B of Fig. 4)

(3) Sugar loss (by analysis) in pounds of sugar per ton of beets (fresh weight) per 24 hours. (See curve C of Fig. 4).

*Data based on average of duplicate 30-beet samples in all cases.

In Table 2 and Figure 5 are presented data on the effect of time of storage on the respiration rates of standard beets. In the figure the rate of sugar loss is plotted against time of storage.

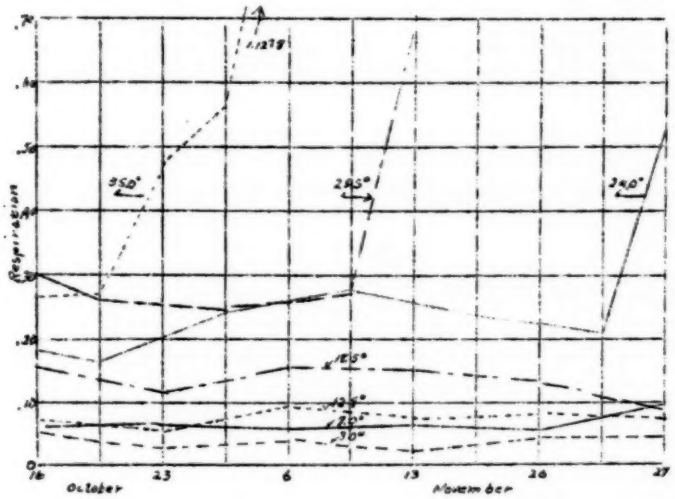

Fig. 5

Effect of Time of Storage from October 16 to November 27 at Various Temperatures on Respiration Rate of Beets.

(Respiration expressed in grams of carbon dioxide liberated per pound of fresh beets per 24 hours).

Table 2.—The Effect of Time of Storage on Respiration Rates of Beets. (Results expressed in grams of carbon dioxide liberated per pound of beets (fresh weight) per 24 hours. Average of Standard 30-beet samples made in duplicate in all cases.)

Temperature	Date Samples											
	10/16	10/23	11/6	11/13	11/20	11/27						
2-3°C.(35°F.)	.054	.027	.042	.024	.049	.041						
7°C.(45°F.)	.056	.062	.057	.063	.051	.098						
12.8°C.(55°F.)	.070	.058	.098	.078	.086	.079						
	10/16	10/19	10/23	10/26	10/30	11/2	11/9	11/13	11/16	11/20	11/23	
18.5°C. (65°F.)	.155	.112	.157	.152	.134	.089						
24°C.(75°F.)	.182	.160		.244	.255	.278	.258	.230	.222	.202	.528	
29.5°C.(85°F.)	.300	.262	.180	.246		.275	.672					
35°C.(95°F.)	.262	.263	.475	.569	1.128							

Temperature readings showed no fluctuations within the pile. The temperatures remained uniformly low, around 3° to 7°C.

Isolations from the interior of the rotten tap roots yielded colonies of Rhizopus nigricans. This organism is not pathogenic to beets at ordinary temperatures.

Calculations indicate that the air, by natural circulation under the conditions of this experiment, moved through the pile at the rate of 16 feet a minute.

Since the results obtained in these experiments indicate a sugar loss lower than was expected, and since natural circulation is apparently faster than was suspected, the feasibility of blowing low temperature night air into the pile to cool it merits further investigation.

In order to determine the keeping qualities of beets under more extreme conditions of size, dirtiness, injury and weather, more investigation under controlled conditions will be necessary.

Summary

At 18.5°C. (45°F.) the standard, bruised, dirty and small beets showed no significant difference in respiration or loss in sugar content. At temperatures below 24oC. the standard beets showed a close relationship between temperature and respiration rate or sugar loss. At temperatures of 24° C. and higher, the rate of respiration increased more rapidly in proportion to the temperature rise than at the lower temperatures. This behavior was in close agreement with the condition of the beets at the various temperatures, since observations showed that the lower temperatures retarded or inhibited mold and rot, while rapid decomposition took place at the higher temperatures.

Under the conditions which obtained in this experiment, it may be concluded that wounding, or the presence of reasonable quantities of foreign material mixed with sugar beets, caused no important change in the rate of respiration or sugar loss.

RESULTS OF FIELD TRIALS OF BORON AND TREATED SEED IN THE GREAT LAKES COMPANY TERRITORY

M. W. Sergeant[1/]

(a) Field Trials of Boron

General Notes

Beets are among the high boron containing plants, according to the French investigator, G. Bertrand.

When boron is known to be needed, about 20 pounds of borax per acre is a good general recommendation. Since all boron is not used by the first crop subsequent applications of 5 to 8 pounds per acre will suffice when beets are

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1/ Great Lakes Sugar Company

again raised on the same ground. Too liberal use is not recommended as high concentrations remaining in the soil are dangerous to the best growth of later crops.

The results from the limited work done this year are inconclusive and the differences insignificant in most cases.

A difference in results was apparent between factory districts. This may be due to different soil conditions but seems more likely to reflect the way in which the work was conducted.

The Boron vs. Check Plot tabulation and the Varying Amounts tabulation marked "Ohio #2" seem most likely to be reliable because they bring out fairly uniform trends rather than a reversal as in the tabulation marked "Ohio #1."

Boron Plots vs. Check Plots*

Results from 12 Fields in 4 Districts

Avg. % Stand		Avg. T. Yield		Avg. % Sugar		Avg. % Purity		Avg. lbs. Sugar/A.	
Boron	Check	Boron	Check	Boron	Check	Boron	Check	Boron	Check
70.9	73.2	12.82	13.36	16.5	16.3	83.5	84.4	3539	3653
	+3.3		+0.54	+0.2			+0.9		+114

*(10, 15 and 20-pound Boron applications compared with checks)

Boron in Varying Amounts

(Mixed with fertilizer - drilled in with the seed)

Ohio #1	Boron Lbs./A	Avg. % Stand	Avg. T. Yield	Avg. % Sugar	Avg. % Purity	Avg. lbs. Sugar/A.
2 plots	0	76.2	14.02	16.4	86.5	3977
3 plots	10	73.0	15.21	18.2	85.2	4716
2 plots	20	77.5	15.30	16.8	86.5	4448
1 plot	25	70.0	12.70	14.4	79.7	2915
2 plots	60	57.5	13.61	18.2	84.5	4186

Ohio #2	Boron Lbs./A	Avg. % Stand	Avg. T. Yield	Avg. % Sugar	Avg. % Purity	Avg. lbs. Sugar/A.
1 plot	0	82	14.87	16.85	83.8	3245
1 plot	10½	73	13.49	17.2	83.0	3851
1 plot	21	67	12.0	16.1	83.4	3222
1 plot	63	39	7.69	15.7	79.1	1908

Note: All Boron used in the form of Borax.

The tabulation indicate that small quantities of Boron may improve yields but that the stand is reduced proportionately, as increasing amounts are used, to the point where yields are seriously reduced also.

The reduced stand may be due to use of Boron in the row with the seed. In another demonstration plot where the Boron and fertilizer were broadcast the stand increased directly with the increased Boron up to 60 pounds but the yields diminished above 25 pounds of Boron.

This year's results suggest caution in the use of this element both as to quantity and as to method of application.

(b) Field Trials of Treated Seed

One of our districts tried treated seed rather extensively in 1938 and felt that some benefit was received. This year they used both ready-treated European seed and seed treated with mercury dusts prior to planting. This was done on a whole field basis, however, and the only information we hope to get is the comparative results of all treated and untreated seed fields.

(16 Fields in 3 Districts)

Avg. % Stand		Avg. T. Yield		Avg. % Sugar		Avg. % Purity		Avg. lbs. Sugar/A.	
Tr.	Check	Tr.	Check	Tr.	Check	Tr.	Check	Tr.	Check
66.8	69.0	12.88	12.61	15.9	16.3	83.9	85.7	3436	3520
	+2.2		-0.27		+0.4		+1.8		+84

(German and Danish treated seed - 1 variety each)

The results tabulated above show insignificant differences between treated and untreated seed and do not indicate that any expense or trouble is warranted in treating seed to prevent blackroot or to increase yields in our area unless new and more efficient treatments are available.

(9 fields in 1 District)

First seedings lost with blackroot (untreated seed).
Reseeded June 23 to July 1, inc. with treated seed.
Seed treated with Cuprocide 54 spray.

Acres reseeded	81.51
Acres lost a second time	28.39
Acres saved from second seeding	53.12
Reseeded fields wholly lost	0
Reseeded fields partially lost	4
Reseeded fields wholly saved	5

Average of Saved acreage	Yield	Sugar content (by refractometer test)
	6.92 T.	16.3%

The yield and sugar content of these fields seem fairly satisfactory in view of the very late planting date.

Warmer weather and better growing conditions may account for the fact that no field was entirely lost a second time. (94% of one field was lost, however).

The question arises as to whether better yield and sugar content might not have been produced by saving the best 53.12 acres of the original stands and carefully working them, at the proper time. Unfortunately no data or proof can be given to support or refute this idea.

Since no check plots were kept in these fields the results are subject to your own interpretation.

PHOSPHOROUS DEFICIENCY BLIGHT OF SUGAR BEETS
often called
BLACK HEART BLIGHT

R. A. Jones[1]/

In 1926 A. R. Williams, fieldman in the Wheatland Wyoming Beet District of the Great Western Sugar Company, had in his territory a field of beets that was dying from some unknown cause. The field had been in corn the previous year, and for sixteen years before that had been in alfalfa. In August a good portion of the beets had died except along certain irregular strips. On these strips the beets were normal and it developed that they were exactly on positions where refuse sweet clover had been hauled and burned before the field was plowed for beets.

The facts regarding the case were examined by several observers among whom was Asa C. Maxson, Superintendent of the Great Western Experimental Farm. His conclusions were that it was a nutritional problem, and the missing element had been supplied from the ash of the burned sweet clover. There seemed to be two possibilities, it was either potash or phosphorous or both that had made the difference. The next year tests were made with these two elements and it was definitely proven to be a phosphorous deficiency. Treblesuperphosphate alone corrected the difficulty, which ever since has been known as Black Heart Blight.

A study of the reoccurrence of the so-called Black Heart Blight has been conducted in Montana, Wyoming, Nebraska, and Colorado the past year. The first noticeable symptom in the leaves of beets suffering from a lack of phosphorous is a slight burning around the edge, which in later stages may cause the death of the entire leaf. As the damage progresses the leaf tissue dies between the veins.

In fields where the fertility is high in all respect except for phosphorous, and the leaves are large there often appears the copper colored leaf. This type of leaf is not positively identified with phosphorous deficiency, but always does occur along with the positive symptoms. It may be called the "paralytic" leaf. It is small with edges rolled inward from the sides and also from the top. The leaf thus resembles a paralytic hand with the fingers drawn

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1/Anaconda Sales Co.

inward. The tissue between the veins is usually dead. The appearance of the leaf is best shown in the transparencies and actual specimen exhibited at the side. As far as is known this leaf is a positive symptom of phosphorous deficiency and is never the result of any other cause.

Another very typical leaf symptom is shown in the attempt of the beet to put out small leaves at the center of the crown. As the larger outer leaves die the beet attempts to recover by putting out new leaves. In extreme cases however, all leaves die and the root succumbs to the ordinary processes of decay.

Root systems are less easily identified than those in the leaves. In the great majority of cases there is no apparent disorder in the root except its small size. Beets suffering from extreme phosphorous deficiency seldom reach a size of over three inches in diameter. More often they are one-half to one and one-half inches in diameter in the late summer or fall. The first pronounced root symptom is found as a small brown spot on the shoulder of the beet or in a recess usually not over half-way down on the root. Sections of the same beets show that the discolored portion is near the outside, or apparently develops from the outside, inward. The dead portion of the root develops as does the dead portions of the leaf. In the leaf the veins or main channels of food distribution are the last portions to be affected. At the outer edge it is more difficult to transport food materials, hence if there is a shortage of nutritive materials the most distant points are affected first. The same is apparently true with the root. Dead tissue forms at the shoulder or portion most distant from the source of food supply.

Phosphorous deficiency has been designated by various terms, Late Blight, Root Blight, and especially Black Heart Blight. Late Blight and Root Blight are quite appropriate but Black Heart Blight is confusing. As stated above phosphorous deficiency affects the shoulder of a beet or a recess lower down. The process of decay only reaches the heart of the beet in most severe cases. The term Black Heart Blight is more applicable to Rhizoctonia or Fusiarium. It is very poorly applied to the effects of phosphorous deficiency. A better term would be phosphorous deficiency blight, or for short P.D.B.

The indications are that the blight is not a disease. No organism has yet been definitely associated with it. The ordinary organisms of decay, of course, enter the beet and carry out its destruction after death takes place in the tissue by starvation.

The final proof that the symptoms just described are the result of phosphorous starvation is found in the fact that a field of beets showing the symptoms will recover when treated with a phosphate fertilizer. Several such demonstrations have been made in the Wheatland area. The recovery can never be complete, of course, but beets that have been almost completely defoliated for want of phosphorous can be made to grow an entirely new set of tops when side dressed with phosphate fertilizer.

A typical case of phosphorous deficiency blight occurred in the Greeley, Colorado, district this year. William Nicholson, who had experienced the blight in the Wheatland territory, was in charge of the field at Greeley. On the twelfth of August four rows were side dressed with phosphate. Within thirty days there were good tops on the treated beets, while the adjacent beets on each side were either dead or had very poor tops.

Samples dug from the treated portion indicate a yield of eight tons per acre as against the yield of five tons per acre on the untreated portion of the field. It is obvious that it would be impossible to produce a good yield by correcting a difficulty as late as the twelfth of August, but the fact that the tops grew again on the beets is sufficient evidence that phosphorous was the cause of the blight.

The literature, and especially that from Utah, describes what is termed "Late Blight," which according to the evidence presented is phosphorous deficiency blight. It is stated that late blight is very greatly favored by drought and that in past years has caused great losses to the beet growers in Utah. Drought, of course, causes phosphorous deficiency according to the ordinary laws of solubility. When moisture decreases, soluble phosphorous decreases, or in other words, phosphorous is not dissolved from the soil and hence the crop suffers for lack of this element.

Moisture affects solubility of phosphorous in still another way. Carbon dioxide is the principal means by which the phosphate in the soil is made available. When moisture is limited bacterial activity and the formation of carbon dioxide is also reduced. Furthermore the activity of the crop itself is retarded by lack of moisture and there is a corresponding decrease in the amount of carbon dioxide given off by the plant. The reduction of moisture thus causes a reduction of available phosphorous and a deficiency occurs.

The publications from Utah also state that a high pH favors phosphorous deficiency. This again is in full accord with the principles of solubility. As the pH rises or the soil becomes more alkaline phosphates are held in a more insoluble state. The deficiency is thus favored by a high pH which is according to the findings in Utah.

Phosphorous deficiency blight occurs only in extremely deficient soils. Actually such soils represent a small percentage of the total beet acreage. On these soils the crops usually do not pay more than the cost of harvest, and sometimes not even that amount. They do illustrate in the communities where they occur, how near the danger line the soils are becoming as regards the supply of phosphorous.

The symptoms of mild phosphorous deficiency cannot be detected in the plant. From an economic standpoint it is this unnoticeable handicap or deficiency that really reduces production on a large acreage. The extreme symptoms of deficiency as discussed calls to our attention the need of more watchfulness regarding the phosphorous supply in average soils or fields that have not yet become depleted to the danger line.

Note: A series of "color" photographs were shown which illustrated clearly the phosphorous deficiency symptoms of leaves and roots at various stages of development.

APPLYING FERTILIZERS TO SUGAR BEETS IN ONTARIO

H. W. Brown[1]/

Sugar beets have been grown as a commercial crop in Ontario, Canada, for 40 years. It is the purpose of this short presentation, to show what part commercial fertilization plays in the production of this crop and what is the

1/Agricultural Research Dept., Canada and Dominion Sugar Co.,Ltd.,Chatham,Ont.

basis for recommendations to beet growers in regard to the use of fertilizers.

In the early days of the beet sugar industry, barnyard manure was the only fertilizer applied to the crop, but gradually the beet growers came to recognize the value of commercial fertilizers and found both the quality and the yield of beets was improved thereby.

The outline of this presentation is as follows:

1. Rates of commercial fertilizer application used by beet growers.
2. Yields obtained by "users" and "non-users" of commercial fertilizers.
3. Types or brands of fertilizer used by growers.
4. Methods of fertilizer application.
5. Soil testing and soil analyses for beet crops.
6. Research program for meeting beet crop needs as to fertilizers.

1. Rates

Records compiled from individual beet growers show a wide variation in the rate of commercial fertilizer used. The following table gives the percent of acreage upon which fertilizer was used at various rates, for all beet growers in Ontario, who number about 4000 per year:

Table 1 - Percentage of sugar beet acreage using various amounts of commercial fertilizer and average application per acre.

Year	125# or less	125#-200#	200#-300#	Over 300#	Av. application
1938	19.4%	17.9%	53.2%	9.5%	178 pounds
1937	17.8	18.2	55.9	8.1	213 "
1936	17.3	18.8	52.0	11.9	185 "
1935	4.1	32.3	58.0	5.4	195 "
1934	3.1	26.4	57.4	13.1	206 "
5 Year Av.	12.4	22.7	55.3	9.6	195 "

This table shows that the average grower applies about 200 lbs. per acre and not more than 10% use over 300 lbs. per acre. The increasing percentage with one bag or less per acre reflects the economy on expenditures as the farmers felt the depression effects more and more.

2. Yields

Less than 10% of the beet growers will now try to grow a crop of beets without commercial fertilizer. Over the past 5 years, 90.9% of the beet acreage received some commercial fertilizer. When we compare the average yield of beets for all growers who fertilized with all those who did not use commercial fertilizer, we obtained the following results over a 5 year period:

Table II - Percentage of fertilizer users and non-users with average yields per acre

Year	Users	Non-users	Users Yield	Non-users Yield	Increase for users	Value of Extra Yield
1938	92.2%	7.8%	9.67 tons	8.64 tons	1.03 tons	$5.28
1937	91.3	8.7	7.83 "	6.72 "	1.09 "	5.06
1936	88.6	11.4	11.00 "	9.90 "	1.10 "	5.47
1935	90.0	10.0	8.53 "	7.64 "	.89 "	5.00
1934	92.4	7.6	9.89 "	8.99 "	.90 "	6.23
5 yr. av.	90.9	9.1	9.38 "	8.38 "	1.00 "	5.41

We did find that the 9.1% not using commercial fertilizer are chiefly

"older" farmers who have never used it on any farm crop or those who pride themselves on the use of farm manure or clover in rotation. Despite this positive selection of the 9.1% toward good farm practice, the growers who have used commercial fertilizer have outyielded the non-users by an average of 1.0 tons per acre over a 5 year period. The increased return has been $5.41 per acre for an expenditure not over $3.00 per acre. In addition to the merit of increased returns, the fertilizer saved the land from more rapid depletion of the fertilizer elements and also had a "carry over" effect upon succeeding crops on that land.

3. Kinds

The kinds or analyses of fertilizers used on the beet crop are the outgrowth of many factors including Fertilizer Companies marketing publicity, Agricultural College bulletins, crop analyses and soil analyses. The lower analysis materials have been replaced with higher grades, and the Sugar Company has made recommendations based upon field tests and soil analyses.

The following table gives the chief fertilizer mixtures used by Ontario beet growers during the past five years:

Table III - Kinds of fertilizers used for beets by Ontario growers, given as percentage of acreage for various mixtures.

Year	2-16-6 Analysis	2-12-10 Analysis	2-12-6 Analysis	0-20-0 0-16-0	Other Mixtures
1938	64.0%	3.6%	24.2%	4.2%	4.0%
1937	58.2	4.2	28.1	5.2	3.2
1936	64.4	3.0	25.1	3.9	3.6
1935	74.4	7.9	12.0	3.5	2.6
1934	61.9	0.0	33.0	4.1	1.0
5 yr. av.	64.6	3.8	24.5	4.2	2.9

This table shows that about 95% of the fertilizers used in Ontario on sugar beets are mixed or "balanced" fertilizers. The 2-16-6 has become the most widely used fertilizer, averaging 64.6% of the crop. It was introduced as an improvement on the 2-12-6 fertilizer, which in turn was an advance over the 2-8-6. The 2-16-6 was introduced to meet the needs of the sugar beet crop on most Ontario farms. The Nitrogen content is low (2%) because Nitrogen can be incorporated into the soil more cheaply in manure and clover, but this small amount starts the crop off well. In numerous field experiments it showed a faster early growth than where it was omitted. The phosphate content is high (16%) because field trials have repeatedly shown a marked response to Phosphate application in Ontario soils. Analysis of Ontario soils (Table VI) have usually shown a low content of available phosphate. The 6% of Potash included in the 2-16-6, or 10% in the 2-12-10, has two chief merits. Firstly, it supplies part of the high Potash requirement of the beet crop, and secondly, it lessens the drain on the soil Potash supply which may be adequate at present but will be a deficiency if no replacements are made.

Some data on relationship of clover and manure of the Ontario beet crop is important to the picture being presented. The following table shows how these Nitrogenous materials are related to the beet crop:

Table IV - Percent of sugar beet acreage with clover and manure.

Year	Manure Applications			Clover in Rotation	
	Same Year	Previous Year	Tons per Acre	Previous Year	2nd Yr. Back
1938	5.3%	23.9%	13.6	13.1%	30.0%
1937	4.7	27.6	13.5	16.5	29.2
1936	3.1	25.9	14.2	1.1	15.7
1935	3.3	27.4	13.7	0.3	15.5
1934	5.8	31.7	12.4	0.3	27.4
5 Yr. Av.	4.4	27.3	13.5	6.3	23.6

This data shows the relatively small percentages of beet acreage being manured or clovered at a time likely to increase the Nitrogen content for sugar beets. With only about 30% of the acreage getting a direct effect of clover and manure, the tonnage yields of sugar beets are relatively low on many Ontario farms. This is one of the main reasons for the wide variations in yield often found on neighboring farms.

4. Application

The methods of applying fertilizer to sugar beets are the direct outcome of the type of equipment sold to growers for seeding their beets. The combined seed and fertilizer drill was introduced nearly 20 years ago, and the fertilizer has been applied with the seed on at least 90% of the acreage receiving any fertilizer. The beet drills now used by practically every Ontario grower deliver the seed and fertilizer into one tube and let them mix while dropping from the separated seed and fertilizer boxes.

The mixture of seed and fertilizer drops into a shallow furrow made by a pair of discs or a runner shoe and is left there at a depth from 1/2 inch to 2 inches below the surface. The soil texture and pressure put upon the discs or shoes regulates the depth of seed and fertilizer. The intimate contact of seed and chemical fertilizer has both benefits and disadvantages for the beet crop.

On the positive side, the young seedling is assured of adequate plant nutrients in the early stages of growth, if there is sufficient moisture to dissolve the fertilizer elements. In S. W. Ontario, where the sugar beets are grown, there is an average rainfall of 29.0 inches, of which more than 5 inches occurs in April and May while seeding is being done. Under normal conditions the beet seedlings obtain adequate nutrients, as our plant tissue tests or chemical analyses of seedlings show. Unfortunately, there are abnormal seasons and every year there are abnormal districts where the rainfall is just sufficient to form a very concentrated nutrient solution which injures or kills the tender seedlings.

Numerous case histories have shown injury to seedlings by fertilizer, and the stand in some cases has been seriously lowered. Yields have been reduced as they are at J. R. Shuel's in 1939 when "No Fertilizer" yielded 12.7 tons per acre while with 500 lbs. of 2-12-6 the yield was only 12.0 tons per acre and the "set-back" was noticeable all spring. At H. Maitre's, stand counts were reduced 13% where fertilizer was applied with the seed, and some growers have torn up beet crops where the stand was too poor, apparently because of fertilizer burning.

The rate of fertilizer application becomes very important when the fertilizer is applied in contact with the seed. Field experiment results with triple superphosphate, double strength 2-12-6 and Ammo-Phos brands showed that they could not be safely applied at the rates commonly used. With the analyses now used, the rates must be held to 250 pounds or less to avoid damage to the seedlings and injury may occur even then under certain moisture conditions.

To increase beet yields and ensure a profitable crop, it is often necessary to apply more than the amount which can be safely mixed with the seed. Two alternative methods of application are being adopted and should be encouraged, despite the use of more complex machinery or additional work at seeding time. One new method in Ontario is to use a drill with separate fertilizer delivery tubes which will place at least part of the fertilizer away from the seed, and the second is the application of part of the fertilizer at a different time.

Every bit of complexity in the beet drill not only increases its cost, but increases the mistakes in uniform seeding by unmechanical or careless farmers. Even the "split shoe" drill, which is the simplest separate seed and fertilizer adaption, increases seeding mistakes. In this drill there are twice as many tubes to "go wrong" and a number of our growers had difficulty in the tubes "plugging".

The second alternative to injuring the germination with fertilizer is to apply part of the material, broadcast, as a side-dressing or with a grain drill. Our experience in Ontario with side-dressing the beet rows, has not proven marked benefit for this practice over pre-seeding applications of the same fertilizer. Side-dressing after thinning means considerable work with extra equipment, and the increases in yield have usually only paid the additional expense. Nitrogen applications after thinning often increase the tonnage, but give a lower sugar content crop which about balances the value of increased yield. Our best results in Ontario have come from a generous application of Phosphate with the grain drill just before seeding, and the use of a balanced fertilizer like 2-12-10 at 125 - 250 lbs. per acre with the seed. There is scope, however, for improvement in machinery and further research upon deeper fertilizer application and its effect upon the seed bed. Our experience indicates that any benefits derived from deeper placement of fertilizer are nullified if the seed bed is disturbed under the row.

5. Crop Needs and Soil Contents

The fertilizer application should depend upon the soil content of available plant food and the particular crop needs. We have made analyses of Ontario beet roots and beet tops as well as followed the crop through the season with tissue tests. The crop needs for a 10 ton per acre crop of Ontario beets, as published in the Society's report of the Detroit meeting in 1939, involve 97 lbs. of Nitrogen, 23 lbs. of Phosphorous, 129 lbs. of Potash and 44 lbs. of Lime, found in 5550 lbs. of dry matter including crowns and leaves. These fertilizer elements would be found in approximately 500 lbs. of Sulphate of Ammonia (20% N), 115 lbs. of Superphosphate (16% P_2O_5) and 215 lbs. of Muriate of Potash (60% K_2O). It would take 2000 lbs. per acre of a fertilizer mixture approximating an analysis of 5-2-7.

Fortunately for the sugar beet growers, the beets are grown in soil, not in a solution, and the soil is able to supply most of the crop demands. Unfortunately for our problem, the total fertilizer ingredients in the soil are not available to the growing plants, and the old method of "Total Analysis" of a soil does not give the right answer to fertilizer requirements. Our methods of estimating "Available" plant nutrients are constantly changing and every year we have "better and better" methods thrust upon us.

Our laboratories have used the Azotobacter Test, Morgan's, Brya's, Truog's, Thornton's Method and the Neubauer Test as well as several modifications of our own. The following soil analyses of typical sugar beet growing soil will show the general conditions in Ontario.

Table V - Analyses of typical sugar beet soils in Ontario.

Soil Type	Soil Series	x-Total Org.Matter	xx-Active Org.Matter	O.M.Rates A/T	Thornton's Phosphate	Truog's Potash
Clay	Brookston	6.3	3.9	64%	116#	546#
Clay Loam	"	5.3	3.1	57	87	323
Sandy Loam	"	4.9	3.1	65	73	273
Clay	Clyde	11.6	6.3	57	117	361
Silt Loam	"	10.4	6.0	58	50	226
Clay Loam	Thames	5.8	3.3	56	84	438
Clay	Haldimand	3.4	2.5	74	17	263
Clay Loam	Perth	5.1	4.0	79	5	341

x Method = Potassium dichromate under special heat.
xx " = Sodium " under heat of reaction.

Soil Type	Soil Series	H-ion pH	Total Nitrogen	Neubauer phosphate (P_2O_5)	Neubauer Potash (K_2O)
Clay	Brookston	7.1	.282	83#	896#
Clay Loam	"	7.3	.288	64#	564
Sandy Loam	"	7.3	.257	42#	552
Clay	Clyde	7.4	.512	57#	421
Silt Loam	"	7.6	.291	58#	356
Clay Loam	Thames	7.6	.241	46#	529

x = Hydrogen ion by quin-hydrone. xx = Total Nitrogen by Kjeldahl digestion.

These analyses indicate that the soils on an average contain sufficient of these elements for the beet crop if it were all obtainable by the plants. However, the root system is not able to penetrate every inch of soil and only a fraction of it is within reach of the crop. Insufficient moisture also prevents the plants obtaining what is in available form since plants can only take in food when it is in solution. Such soil analyses as the above have to be interpreted in terms of the plant response and field trials enable us to set limits of low, high or deficient contents. Thus, when a soil shows less than 100 lbs. of available Phosphate, we know that the beet crop will respond to that element in a fertilizer. The Potash content is apparently from 5 to 10 times that of the Phosphate soil content, so that the fertilizer applications should contain more Phosphate, in order to keep it from being a limiting factor in root development.

6. Research Program

Soil analyses must go hand in hand with field experimentation to find the levels of fertilizer response for each soil type. In our Ontario soils the sugar beet crop generally responds to Phosphate, but the Potash content must not be neglected or it soon will become a limiting factor. The wise farmer adds some Potash to his field each year to maintain a high Potash level, particularly for sugar beets which use so much of it.

Our research program in regard to fertilizers involves a record of the crop history for each field where beets are grown and an attempt to interest the farmer in the fertility level of that field. We collect soil samples from each locality and encourage farmers to send in soil samples for free testing and fertilizer recommendations. Soil maps are of considerable help in locating soil types sent in, and these soil types have plant food characteristics which help in recommending fertilizers. Due to wide variations in the soil types, the soil analyses, even with a field kit such as Thornton's, are valuable in estimating the crop needs on special fields. The farmer's cropping system, if he used clover crops in good rotation series, have marked effects upon the fertility level and modify the fertilizer recommendations.

Unless there are special qualities of a soil proposed for sugar beets, our recommendations are for a 5 year rotation to include clover the second year preceding beets, with a heavy manure application on the crop preceding the beets. If the mineral elements are low, then fertilizers are recommended to build up those elements near the deficiency level. Clover and manure can supply most of the Nitrogen needed, but the Phosphate level in Ontario soils is usually so low as to need special application of superphosphate, in addition to the "balanced" fertilizer recommended to go in with the seed. Potash applications do not usually show much response in the beet crop, but the plants use it to a degree which merits some addition to the soil growing beets.

Cooperative field experiments are placed in various localities each year and these act as demonstrations of fertilizer benefit as well as furnish data on the field response of sugar beets to the analyses under test. We feel that much still remains to be done in persuading farmers to stop burning straw, to adopt better rotations and apply more fertilizer for this special cash crop. The general production can be raised much higher apart from disease control, and more productive seed types, if the proper fertilizer analyses are used in the proper quantities and put in the right place.

THE EFFECT OF SOIL STRUCTURE ON SUGAR BEET GROWTH

by
R. B. Farnsworth and L. D. Baver[1]

The sugar beet producing region of Ohio is located in the northwestern quarter of the state. The sugar beet enterprise is, however, concentrated in the Maumee Basin or the old Glacial Lake Plain. The soils of this area are of lacustrine and glacial origin and are mostly of a very heavy nature.

The Paulding, Toledo, and Brookston series comprise the major soil groups of the area (I). The Paulding constitutes a large portion of the flat area west of central Henry and Putnam counties, and nearly all of Paulding county. The soil is principally a heavy clay, exhibits a high moisture-holding capacity, and has a high organic matter content. The Toledo clay is almost as heavy as the Paulding, has almost the same content of organic matter, and is highly retentive of moisture. This clay with the associated classes: silty clays, silty clay loams, and clay loams make up the soils of the beet producing area of eastern Lucas, north central Sandusky, and Ottawa counties.

The Brookston soils overspread the area eastward from the Paulding soil and intersperse the area of the Toledo soils. They are less heavy than the Paulding clay, slightly gritty but almost as dark. The principal soil classes, in addition to the clay, are silty clay loam, silty clay, and silt loam. Throughout the above areas are several light-colored soils ranging from sandy to heavy with respect to texture.

During the last few years evidence has been brought out which indicates that beet yields in these areas are frequently limited by unfavorable physical conditions of the soil. In a recent publication (II) data from the Agricultural Statistics of the U.S.D.A. were presented which show a gradual decrease in acre

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yield of beets in Ohio from an early date in the enterprise to the present. The equivalent decrease was approximately three to four tons per acre; whereas several western states showed a continued increase of one and a half to two tons per acre during the same period. Extensive use of commercial fertilizers on beets in the Ohio territory has failed in many areas to bring about an increase in acre yield.

The physical condition of the soil is of primary importance in the production of a suitable yield of any crop. It is of especial importance in regions where the soils are of an extremely heavy nature.

With the advent of commercial fertilizers the idea developed in many sections of the country that a "cure all" was now available for plant deficiencies and there need be no great concern over the old idea that the fertility elements of the soil would one day become depleted. The rousing interest in plant nutrients was so very marked that the importance of the physical condition of the soil was crowded somewhat into the background.

The physical condition of a soil is referred to by the farmer when he states that his land is in a poor, or in a good state of tilth. His interests seem to lie in the nutrient content of the soil rather than in the factors which may have been responsible for the state of tilth.

The soil system is composed of three phases -- solid particles, air and water. The solid phase is made up of various sized particles. It is the arrangement of these particles, that is, the way they are "put together" in the soil, that greatly determines the air-water relationships of a particular soil. This arrangement of soil particles, the size and shape of the aggregates, is known as soil structure.

The term "soil structure" is more or less descriptive and as such is not capable of being expressed by any specific measurement or number. Measurements of the physical properties of the soil, which are dependent upon structure, can be made and any of these measurements can be used as an index of soil structure. Measurements of soil aggregation, macro- or microstructure, may be used as an index of soil structure. Other measurements that have been used as indices of soil structure are volume weight, total porosity, capillary and non-capillary pore space, and air movement, the pull on the drawbar of a tillage implement, and penetrometric measurements, that is, the force required to press a sharpened instrument into the soil.

The development of an ideal root system of a plant is dependent upon the existence of the proper air-water relationships in the soil. In this case porosity, non-capillary and capillary pore space, and drainage are important factors.

Recent investigations in some newer concepts of how plants feed point out the necessity of a well-developed root system. Root-soil contact is of major importance in plant growth and a well-developed root-system consequently results in a better root-soil contact and a more economical use of fertility elements. If a soil cannot supply the proper air-water relationships the development of the plant roots will be affected. It is often that many soils have a very low percentage of non-capillary pore space and the capillary pore space is filled with water a large portion of the time. The consequent result of such a condition is poor root development, insufficient aeration of the plant roots, a small amount of root-soil contact, an uneconomical utilization

of fertility elements, and a low crop yield.

The optimum plant growth is obtained when there is present in the soil sufficient nutrients and a proper air-water relationship. A suitable physical condition of the soil is important for optimum growth of any plant. In the case of where the root itself is the crop the physical condition of the soil is of utmost importance.

Clay soils ordinarily have a non-capillary porosity of 5 to 10 percent. This has, in the past, in Northwestern Ohio, been sufficient for growth of sugar beets. With an already relatively low non-capillary porosity it is reasonable to believe that very much of a decrease in this porosity would affect plant growth. German investigators have reported that optimum conditions for sugar beet growth in their country were obtained in soils containing a non-capillary pore space of about 15 to 20 percent. A high non-capillary porosity is made possible by a high organic matter content and a stable aggregation of soil particles.

The investigations in this particular problem were carried out on the Northwestern Test Farm at Holgate, Ohio, and on privately-owned farms in the lake plains area.

Earlier investigations (III) on soil changes in these areas show that after from 50 to 75 years of cropping there has been a 48 percent loss in soil nitrogen. Virgin soils originally weighing 65.5 pounds per cubic foot, in the upper foot, now weigh 81.7 pounds. The organic matter content has been reduced from 66 tons per acre to 44. Total pore space has decreased from 60.3% to 50.5.

It is evident that the removal of the organic matter has resulted in the compaction of the soil and a loss of pore space. When a soil becomes compacted not only is there a loss in total pore space but the non-capillary porosity through which air and water readily move is greatly decreased. In some cases the change in total porosity may not be large but the loss of non-capillary pore space (an increase in capillary pore space) is sufficient to affect plant growth. Recent investigations substantiate the above results and show the marked effect these changes are having upon sugar beet growth.

In the fall of 1938 the conditions of a field at Paulding, Ohio, were studied. One-half of the beets had been planted on a continuously-cropped soil. The other half had been planted on land which had been in pasture for eight years, and in corn in 1937. Fertilization and other treatments throughout the summer had been the same. Soil samples were taken at different depths, a stand count was made, and actual yields taken on each half of the field. The following results were obtained:

Table I

CULTIVATED SOIL

Depth of soil sample (inches)	Total pore space (%)	Non-capillary porosity (%)	Apparent sp. gr. (gms.cc)	Beets/ 100 ft.	Actual yield (T/A)
0 - 3	64.0	4.2	.94	55	5.2
3 - 6	62.6	1.9	1.06		
12 - 15	50.8	.87	1.23		

Table I (continued)

PASTURE SOIL

Depth of soil sample (inches)	Total pore space (%)	Non-capillary porosity (%)	Apparent sp. gr. (gms./cc)	Beets/ 100 ft.	Actual yield (T/A)
0 - 3	72.0	6.3	.77	56	8.9
3 - 6	69.2	4.1	.83		
12 - 15	57.5	1.85	1.16		

Table I and figure 1 show that the pasture soil is much less compact than the cultivated soil. The amount of non-capillary pore space is larger and to a depth of 15 inches the pasture soil is much better drained and better aerated. The difference in beet yield is 3.7 tons per acre in favor of the pasture soil.

When experimental work was begun at Holgate the beet production on the farm for the past several years had been about 1.5 to 3 ton per acre. In few instances the yield had been slightly higher.

The effects of soil structure on sugar beet growth were studied. Attempts were made to change the structural conditions by additions of organic matter by various systems of cropping. Manure was also added in different amounts and placed at different depths. A part of the experimental results will be presented in this paper.

In 1937 all plots were planted to corn. In 1938 the following set up was arranged to be planted to beets in 1939.

A - Beets following corn
B - Beets following soy beans (on some plots the crop was removed for hay, on others the beans were plowed under in the fall)
C - Beets following alfalfa
D - Beets following sweet clover
E - Beets following soy beans with manure additions (the entire crop of beans was plowed under in the fall. In the spring 5, 10, and 20 ton amounts of manure were incorporated in the surface three inches of the soil, throughout the plow layer, and under at six inches.)
F - Beets following soy beans, the entire crop of beans was plowed under in the fall and the beets were planted on ridges of from 2 to 8 inches high.

Actual yields were determined on all plots and sugar analyses were made. The percentage of loss in stand was determined by making a stand count after the beets were blocked and thinned and then counting the number of beets harvested from each plot. Total porosity and non-capillary pore space were determined. The results of these investigations are shown in tables II, III and IV.

Table II - The Effect of Crop and Treatment on Yield, Sugar Content, and Percentage Loss of Beets

Number of plots	Crop or Treatment	Yield (T/A)	Sugar Content (%)	Loss in stand (%)
A - 3	Corn	1.54	15.50	48.3
B - 9	Soy beans	3.10	16.55	35.4
C - 18	Alfalfa	3.73	16.32	20.16
D - 5	Sweet clover	4.93	16.80	20.3
E -	Soy beans with additions of manure			
12	5 T. manure*	5.98	16.24	14.3
12	10 T	7.06	16.28	15.6
12	20 T.	7.58	16.23	12.2
F - 24	Soy beans with beets on 2 to 8" ridges	10.12	17.32	17.3

(*) The yield is the combined average of all plots. That is, organic matter additions in the surface, throughout the plow layer, and under at 6 inches are averaged together.

Table III - The Effect of Incorporating Different Amounts of Organic Matter at Different Depths on Yield of Beets
(Soy beans - entire crop plowed under plus organic matter)

Beet Yield (Tons/Acre)

Amount of Organic matter Added	Depth of Organic Matter Incorporation: In Surface 3 inches	Throughout Plow Layer	Under at 6 inches
0	4.41	4.41	4.41
5 Ton of manure	6.01	6.70	5.20
10 "	7.50	6.60	6.60
20 "	7.75	7.70	8.12

Table IV - The Effect of Non-capillary Porosity on Yield and Sugar Content of Beets
(Practices used in effecting porosity changes)

Cultural practices	Apparent sp.gr. (gms./cc.soil)	Total pore space (%)	N.C.P. (%)	Yield (T/A)	Sugar content (%)
Beets following:					
Corn	1.13	55.2	2.66	1.54	15.5
Soy beans (plowed under)	1.13	57.2	4.03	4.41	16.01
Soy beans under with					
5 T. manure in surface	1.03	57.0	5.86	5.00	16.18
10 "	1.03	59.6	6.20	7.75	16.24
20 "	.94	64.5	6.43	10.02	16.74
Ridging 4"	.96	59.3	7.35	11.01	18.35
8"	1.05	58.3	7.54	15.20	18.20

The data in the Tables show a wide difference in beet yield as obtained on plots receiving different cultural treatments. The beet yield following two years of corn was 1.54 tons per acre. The non-capillary pore space of the soil was 2.66% of the total volume. The sugar content was 15.5%; during the season 48.3% of the beets originally on the plots was lost. Beets following soy beans, alfalfa, and sweet clover gave more favorable yields than those following corn. For example the yields after corn were 1.54 tons per acre, after soy beans, 4.41 tons, after alfalfa 3.73, and after sweet clover 4.93 tons per acre. The non-capillary porosity of the soil on the corresponding plots was 2.66%, for corn, and 4.03% for soy beans. Organic matter additions, and ridging of land on which soy beans had been plowed under gave very favorable results. Yields as high as 15 tons per acre were obtained on the ridged plots.

In Table II the yields on the organic matter plots are an average of all plots whether or not the organic matter had been applied only in the surface, throughout the plow layer, or under at 6 inches. The yield on the ridged plots is an average of 24 plots which had been ridged from 2 to 8 inches. In Table IV the yield from the corresponding treatments is that from plots of a specific treatment.

It is not to be understood that any single one of the above methods of treatment is a remedy for the condition existing in the beet-producing area. The ridges in conjunction with organic matter proved especially effective this year. One particular reason for the effectiveness of ridges may be seen in the fact that at Holgate the rainfall in June and July was 8.46 inches and 7.35 inches respectively. The ridged plots were prepared in the fall and the beets were planted after a minimum amount of seed-bed preparation in the spring. This afforded full use of the soil granulation resulting from freezing and thawing during the winter.

Table III shows the relative effectiveness of organic matter additions in different amounts at different depths. Applications of 5, 10, and 20 tons gave increased yields. The 5-ton application was more effective when placed in the surface or throughout than when placed entirely under. This may be attributed to the fact that there is a necessity of keeping the surface layer of soil open. If the surface is closed by the beating action of rain the permeability of the soil to air and water is limited. Ten ton of manure in the surface was more effective than when placed under or throughout the plow layer. The 20-ton application in the surface was the most effective of the surface applications but did not give the results that were obtained when the 20 tons were placed entirely under. Twenty tons of manure under at 6 inches may facilitate drainage and also leave sufficient organic matter throughout the surface to keep the soil open.

Table IV shows the value of a high percentage of non-capillary pore space in these soils. Soils with a non-capillary porosity of 6⅔ percent to 7⅓ percent gave favorable yields. An increase in non-capillary pore space resulted in an increase in sugar content as well as an increase in yield. An increase in the non-capillary porosity of a soil means that there will be present in the soil less carbon dioxide and more oxygen. The presence of oxygen promotes respiration of the plant, greater growth, and more efficient sugar production.

The deterioration of the soil structure in this area has resulted after years of cropping during which time very little, if any, organic matter has been returned to the land. It is reasonable to believe that it will be

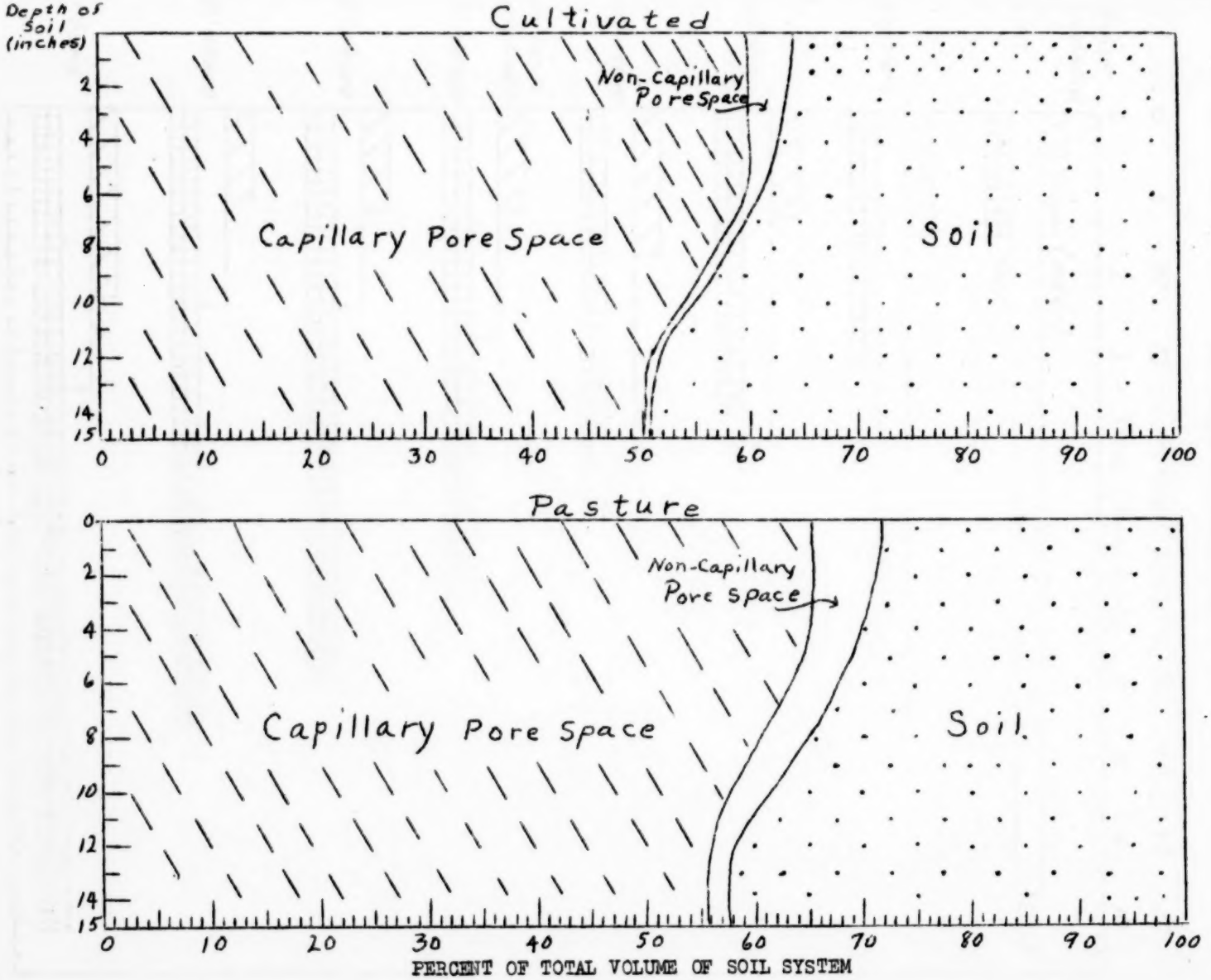
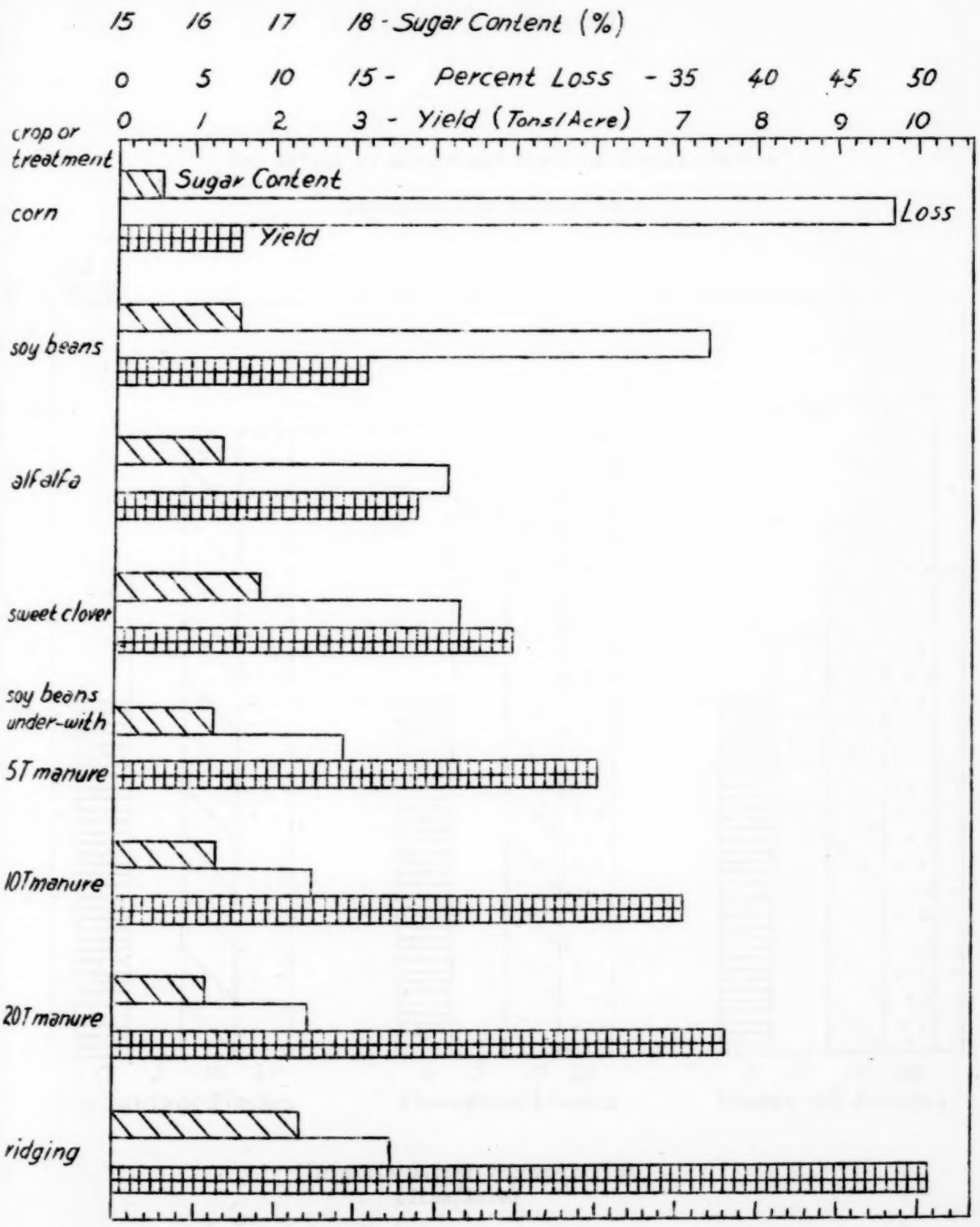


Figure 1 (See Table I)

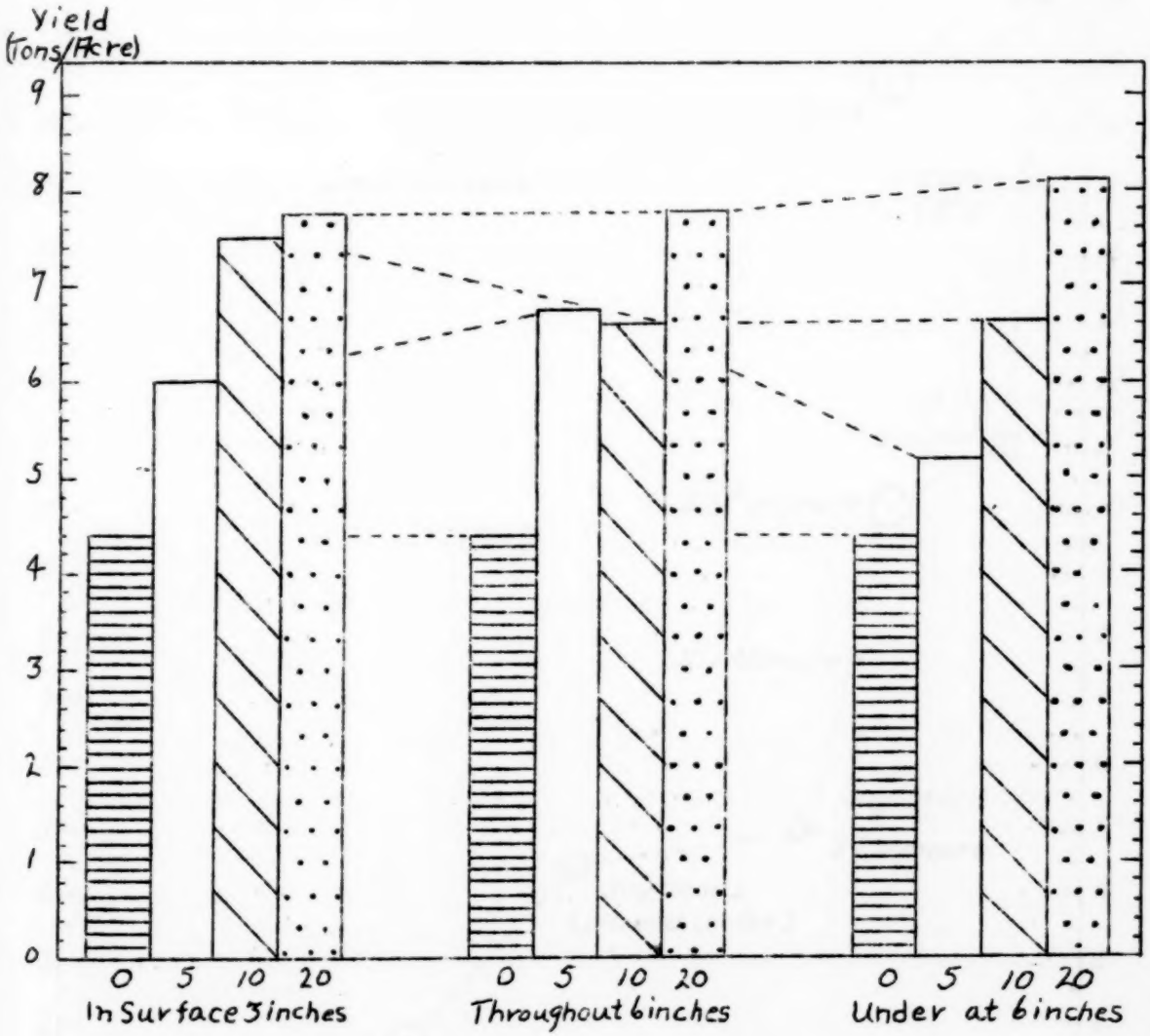
FIGURE 2 (See Table II)



Effect of Crop and Treatment on Yield, Sugar Content and Loss.

Figure 3 (See Table III)

The Effect of Amount and Depth of Organic Matter Incorporation on Beet Yield

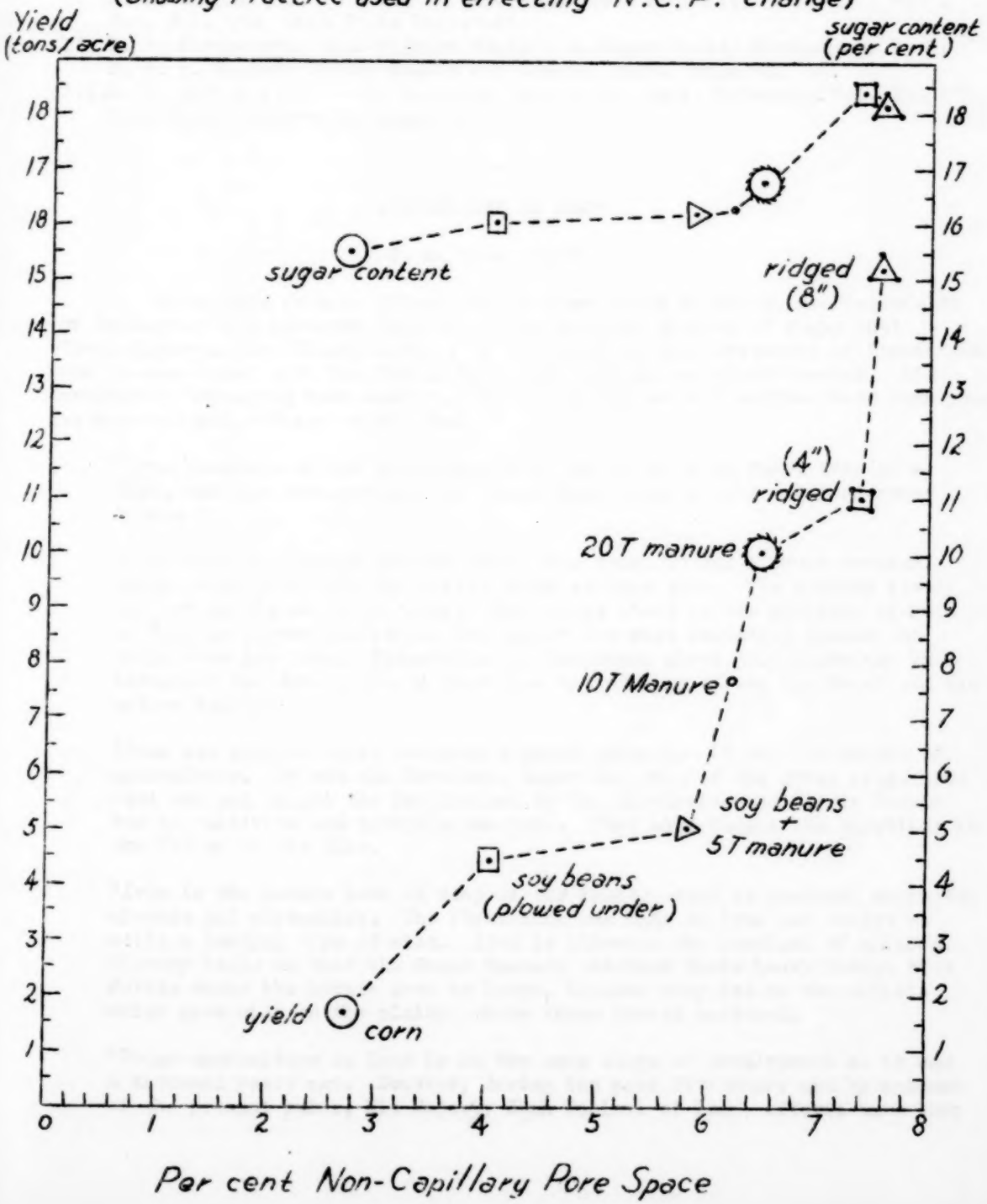


Organic Matter Incorporation
(Tons/Acre)

FIGURE 4 (See Table IV

Effect of N.C.P. on Yield and Sugar Content

(Showing Practice used in effecting N.C.P. change)



impossible in one, two, or perhaps several years to restore an entirely suitable structure to this soil. It is evident however, that organic matter in the form of residues, manure, and green manure crops can be used which will give satisfactory beet yields through their effects on the soil structure.

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"AGRICULTURE IN IRAN"

G. H. Siegumfeldt

Notes made from an illustrated lecture given by Dr. G. H. Siegumfeldt of Denmark at the Agronomy Section of the American Society of Sugar Beet Technologists. Dr. Siegumfeldt is on the staff of the University of Copenhagen and is associated with the Danish Beet Seed Company, as plant breeder. His company is supplying beet seed to Iran and he has several months there each year as Agricultural Adviser to the Shah.

"Iran consists of ten provinces, each one of which is ruled over by a Shah, and the most powerful of these Shahs used to rule over the other Shahs.

"Once, when the Darius dynasty ruled over Iran, it was a great country, which ruled over most the world, known at that time. The country itself was not as big as it is today. The rulers lived in the province of Pars or Fars as it was called and resided in the most beautiful palace the world ever has seen. Persepolis was destroyed about 3000 years ago by Alexander the Great, who at that time killed King Darius the Great and his entire family.

"Iran was also in other respects a great country. It was the cradle of agriculture. It was the Persians, under the rule of the great kings, who went out and taught the Babylonians by the Euphrates and Tigris Rivers how to cultivate and irrigate the land. They also taught the Egyptians in the Valley of the Nile.

"Iran is the native home of many of our fruits, such as peaches, apricots, almonds and pistachios. The first wine was made in Iran and theirs is still a leading type of wine. Iran is likewise the homeland of alfalfa. History tells us that the Roman Caesars obtained their heavy horses from Persia where the horses grew so large, because they fed on the alfalfa which grew wild on the plains, where these horses pastured.

"Today agriculture in Iran is in the same stage of development as it was a thousand years ago. However, during the past five years and by command of the present ruler, His Majesty Shah Pahlevi of Iran, efforts have been

made to develop Iranian agriculture. Among other things, the Shah has ordered that Iran, within five years, shall produce its full supply of sugar.

"The Shah (himself) has paid for the construction of eight beet sugar factories, He plans to build five more beet factories and also one cane sugar mill. However, the question arises in our minds whether Iran with its old farming methods can grow enough sugar beets to supply 13 factories."

The colored photographs of which over 100 were shown, were taken by Dr. Siegumfeldt during his three months sojourn in Iran during the summer of 1939.

The beet fields seen were usually small and often would be under an acre in size. There is practically no farm machinery in Iran, and the land is usually "dug" by heavy hoes and picks. The owner of an oxen-pulled wooden plough is regarded as rather modern, and the usual preparation of the field consists of breaking up the heavy clods which are pulled over by a long-handled hoe used like a pick.

The beet seed has been imported across Southern Europe, or more commonly from Denmark via the North Sea, the Mediterranean and the Black Sea. The beet seed is sown broadcast by hand and raked into the ground. All beet crops must be irrigated, and the areas planted to beets are limited by the scarcity of irrigation canals.

The beets, not being in rows, cannot be cultivated, but the weeds are removed by "pulling" or by hoeing. The weeds are valuable as feed for the farm animals and so are taken home by the field workers for cattle feed.

The beet crop is harvested by hand digging or pulling and the beets usually transported to the local factory by camel. Often a factory manager may have several thousand camels coming to his factory each morning, loaded with factory beets in 300 pound lots.

Danish engineers have built the sugar factories and are assisting in factory operation. The Shah is apparently very much interested in the beet crop and was seen in a number of pictures inspecting the beet fields.

Yields of sugar beets are still very low and variable because of poor land preparation and faulty irrigation, but the agricultural leaders are striving to modernize the farming practices and teach the peasants better ways of farming.

Several slides of beautiful gardens, brilliant with a variety of flowers, showed that Iran has its beauty spots and can produce plants of excellent quality. The agriculturists have many problems to solve during the next 5 years if they are to complete the sugar program of their Shah.

FEED VALUE OF BEET TOPS

N. J. Muscavitch[1]/

By beet tops we mean the leaves, stems and portion of the beet crown which compose the by-product resulting from a normal topped sugar beet. Analyses were made on samples taken from average beet fields near the Scottsbluff plant of The Great Western Sugar Company, at topping time, tops cured on drying racks to keep them out of contact with soil and to allow for the rapid and free circulation of air for rapid drying, and samples fully cured in the

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1/ Great Western Sugar Co.

field by recommended practice. Tests to determine the amount of soil incorporated with the tops at topping time were made during the 1939 harvest. Also during the 1937 season analyses were made on two samples of a good grade, locally grown, second and third cutting alfalfa hay to be used as a basis of nutrition value comparison.

Analysis on Beet Tops at Topping Time

The samples were taken immediately following the toppers and therefore very little loss of moisture occurred before analysis. Date samples were taken and year are shown in the tabulation below:

Date Year	Oct. 7 1937	Oct. 26 1938	Oct. 19 1939	Average
Dry substance	19.32	23.62	16.80	19.91
Sugar (Polarization)	3.51	5.80	3.40	4.24
Crude Protein	2.38	3.37	2.13	2.63
Crude Fibre	2.38	3.17	2.12	2.54
Ash	4.10	3.56	4.59	4.08
Crude Fat	.24	(-)	(-)	(-)
Nitrogen Free Extract	6.71	(7.72)	(4.56)	(6.42)

Crude fat was not determined on samples analyzed on the 1938 and 1939 crops and is included in the figures for nitrogen free extract.

We have a maximum variation of 6.82% in dry substance over the three year period. This can be explained by the influence of the seasons, the maturity of the crop, leaf spot, and light frost affects on the leaves.

Loss of Nutrients and Dry Substance Due to and During Field Curing

During the 1937 season special comparative tests were made on field cured tops and tops dried on special racks to determine the loss of nutrients.

Sampled Date Sampled	From Field 1-4-38	From Drying Racks 1-4-38
Moisture	21.77	15.66
Calculated to Dry Basis		
Crude Protein	11.00	11.80
Crude Fibre	13.62	14.07
Crude Fat	1.33	.94
Ash	18.38	18.10
Nitrogen Free Extract	55.67	55.09

Although the rack drying method is not practical, it does indicate more thorough drying and demonstrates the possibilities of preventing nutrient loss through proper handling of tops during the curing period. The loss of dry substance in curing is further demonstrated by actual weights of beet tops before and after curing as shown: (1)

	Weight of Tops (Lbs.)	% Dry Substance	Pounds Dry Substance
10-7-37 Green Tops	3920	19.32	757.34
10-3-38 Cured Tops	770	84.32	649.42
Loss due to curing			107.92
% Loss			14.25

A portion of the loss shown due to curing is the loss of soil which falls off in the handling of the dried tops but clings to the crisp green leaves. The amount of soil incorporated in the green tops at topping time was determined on a sample taken on October 15, 1939. 200 pounds of tops were divided into two equal portions, one portion thoroughly washed in the factory laundry machine, using cold water, and then both samples were prepared for analysis. The results calculated to a dry basis are shown below:

Beet Tops at Topping Time

	Unwashed	Washed
% Crude Protein	12.66	13.12
% Crude Fibre	12.64	15.87
% Ash	27.34	14.95
% Nitrogen Free Extract Crude Fat	47.36	56.06

Loss in ash, as soil, due to washing is approximately 12%. Since analysis on green and cured tops averages for two years show only 2% difference in ash content on dry substance basis, apparently most of the soil is removed in handling before the roughage reaches the feed yard.

Yield and Analysis on Field Cured Tops

The following data on yield was collected covering two harvests: (1)

Harvest	1937	1938	Totals & Averages
Acres in Field	10.48	7.60	18.08
Tons Topped Beets (Short Tons)	238.60	144.90	383.50
Tons Topped Beets per Acre	22.83	19.07	21.21
Weight of Cured Tops (lbs.)	63090	33400	96490
% Dry Substance - Cured Tops	78.23	85.11	80.61
Weight of Dry Substance	49355	28427	77782
Weight of Dry Substance per ton of beets	206.8	196.6	203

The ratio of dry substance in cured tops to beets harvested is slightly higher than one to ten. Knowing the yield of beets, from this proportion the grower may easily calculate the tons of feed he has available for feeding operations. Tests conducted on yield of tops at Colorado State during some beef fattening experiments report slightly higher yields. Quoting from this report - "The results of this experiment showed that for each 1000 pounds of beets produced the farmer can expect approximately 640 pounds of green tops at topping time containing 80% moisture."(4) If we were to deduct the loss (14.25%) in dry substance due to curing, as found in our tests, Colorado tests yield 17 pounds more dry substance per ton of beets than the Nebraska tests.

In order to make sharper comparisons on the value and change in fodder value due to curing in the field, analyses shown below are calculated to a dry substance basis. The average of two analyses on a good grade of second and third cutting alfalfa hay is included as a basis for valuating the beet tops:

	Sugar Beet Tops						1937
	1937		1938		Averages		Alfalfa Hay
	Topping	Cured	Topping	Cured	Topping	Cured	2nd & 3rd
% Crude Protein	12.34	11.80	14.28	13.78	13.36	12.79	15.07
% Crude Fibre	12.31	14.07	13.43	15.43	12.87	14.75	36.02
% Ash	21.24	18.10	15.07	14.16	18.16	16.13	11.40
% Crude Fat	1.26	.94	( )	( )	( )	( )	( )
% Nitrogen Free Extract	52.85	55.09	(57.22)	(56.63)	(55.61)	(56.33)	(37.51)
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dry Substance on Original	19.32	78.23	23.62	85.11	21.47	81.67	94.80

Comparing the two roughages on protein value, dry substance basis, field cured beet tops for the two years shown have 85% the value of a good grade of alfalfa hay. Loss in protein due to curing was 4.27%.

Well cured beet tops contain a high percentage of nitrogen free extract and closely approach small grains in this nutrient value.

Feed Replacement Value of Beet Tops as Found in Actual Tests

My work on this subject has been primarily with chemical analysis of the fodder. I will now quote from articles on the replacement value of beet tops in various fattening and milk production rations, these appearing in "Through the Leaves," and mimeographed reports issued by the Scottsbluff Experiment Farm.

Conditioning Ewes

On a farm test near Fort Collins, Colorado, a sheep raiser reports "Ewes conditioned on beet tops before the breeding season increased the lamb yield and that as high as 120 lambs to 100 ewes were docked." A percentage he has not been able to achieve on range grass. (2)

Fattening Lambs

The following was taken from feed lot reports issued by the Scottsbluff Experiment Farm. The tests covered a period of three years, ten lots of thirty lambs each, and the tabulation, for brevity, contains all the feeds used in the various rations but only one high and one low feet cost lots from each year of the tests are shown.

From Scottsbluff Field Station Feed Lot Report (5)
Feed Consumed (lbs.) to Produce 100 Pounds of Gain

	Low Feed Cost Rations			High Feed Cost Rations		
	Nov.1938 to Feb.1939	11-8-37 to 2-12-38	11-9-36 to 3-9-37	Nov.1939 to Febr.1939	11-8-37 to 2-12-38	11-9-36 to 3-9-37
No. of days in feed lot	100	96	120	69	96	120
Lot. No.	8	10	7	1	2	7
Shelled corn	-	-	-	511	259	-
Barley	191	125	-	-	-	261
Dried Beet Pulp	-	125	-	-	-	-
Dried Molasses Pulp	-	-	213	-	-	-
Beet Molasses (Johnstown C)	-	111	-	-	-	-

(continued)

(continued)

	Low Feed Cost Rations			High Feed Cost Rations		
	Nov.1938 to Feb.1939	11-8-37 to 2-12-38	11-9-36 to 3-9-37	Nov.1939 to Febr.1939	11-8-37 to 2-12-38	11-9-36 to 3-9-37
Cull Beans	191	-	152	-	-	-
Bone Meal	-	-	-	-	11	12
Wet Beet Pulp	-	789	-	-	-	-
Cotton Seed Meal	-	-	-	-	85	85
Alfalfa Hay	440	185	274	832	-	-
BEET TOPS	539	370	636	-	-	-
Corn Fodder (ears on)	-	-	-	-	-	528
Corn Fodder (no ears)	-	-	-	-	373	-
Feed Cost per 100# Gain	$4.80	$4.66	$4.87	$8.14	$7.13	$13.30

Feed costs were calculated from values prevailing locally during the months and year indicated in the tabulation. It is evident that the rations showing the lowest feed cost per 100 pounds gain contain a large proportion of beet tops, whereas this roughage is entirely absent from the high cost lots.

Mr. E. J. Maynard, in an article on "Decentralized Feeding in Montana" gives the following summary on the value of beet tops in a steer feeding ration. (6) (3).

"The Standard Daily Ration could be summarized about as follows:"

Dried Beet Tops	14 - 16 pounds
Wet Beet Pulp	50 - 75 pounds
Grain	2 - 4 pounds
Dried Pulp	2 - 4 pounds
Bone Meal	1/10 pound

"Variations in the above ration include "C" molasses, mill feed, cut corn fodder, and in a few instances tankage. Indicated daily gains on cattle being fattened on the above rations ranged from 2 to 2-3/4 pounds. An analysis of the ration fed seems to indicate that beet tops were providing the cheapest and most efficient fattening feed in the ration. One pen of 125 cattle pastured on beet tops alone, with alfalfa stubble, for a six week feeding period before being put in the fattening pen had produced an average daily gain of 1.7 pounds per head. Fed in the dry lot rations, beet tops were apparently replacing grain at the rate of 2-1/2 pounds of well cured, dried tops to one pound of grain."

"Based on relative feed values and costs, each ton of dried cured tops (from five tons of beets, and valued at 35 cents per ton of beets) costing $1.75 per ton, was replacing about 800 pounds of grain at a grain equivalent cost of 22 cents per cwt. This low cost grain equivalent value in tops, compared to the 75 cent per cwt. cost of most grains, indicates the saving possible by the use of tops, and also emphasizes the importance in proper conservation and feeding of tops in fattening rations.

Dairy Cattle

Quoting Mr. Paul C. Swanson, Animal Husbandman at the Scottsbluff Field

Station, on the value of beet tops when used in a dairy cow ration: "In comparing the value of alfalfa and beet tops as a cured roughage, the following results are reported: (7) "During the first year's test, 1 pound of alfalfa was equal to 1.1 pounds of beet tops when compared on a dry matter basis. In other words in this test beet tops were 91% as valuable as alfalfa (D.M.B.) without considering the increase in milk yield. In the second year (1938-39) of the experiment, 1 pound of alfalfa was equal to 1.1 pounds of beet tops not considering the increase in milk yield. This gives beet tops a value 83% as great as alfalfa. Taking a mean of the two years together the tops were worth 87% as much as alfalfa on a dry matter basis."

"Estimating cured alfalfa in the stack at 90% dry matter and cured beet tops in piles or stacks at 70% dry matter, beet tops were worth $5.64 per ton the first year and $5.18 per ton the second year when alfalfa is worth $8.00 per ton. The mean of the two years gives beet tops a value of $5.41 per ton when alfalfa is worth $8.00 per ton. (7)

Summary

Dried beet tops are a source of nutrients approaching alfalfa in protein content and the small grains in nitrogen free extract when calculated on a dry basis. Too much emphasis cannot be placed on the value of proper curing and storing of the feed to prevent nutrient loss from unfavorable weather conditions or negligence.

Feeding operations by men who are investigators on the subject have demonstrated the value of Beet tops in the replacement of a large portion of concentrates and alfalfa in rations for fattening cattle and in the production of milk from a dairy herd.

Literature Cited and Other Sources of Data

(1) Mr. D. J. Roach, from office files
(2) Mr. R. A. Brackenburg, "Through the Leaves," November 1939, page 192.
(3) Mr. E. J. Maynard, "Through the Leaves," November 1939, page 181.
(4) Mr. R. C. Rom, "Through the Leaves," November 1939, page 187.
(5) Mr. M. A. Alexander & Mr. Paul C. Swanson, Mimeographed Circulars, Scottsbluff Experiment Station, Sheep Feeding Operations for the three years 1936-37, 1937-38 and 1938-39.
(6) Mr. E. J. Maynard, "Through the Leaves," September 1939, pages 156-7.
(7) Mr. Paul C. Swanson, "Through the Leaves," March 1939, page 59.

DUSTING AND SPRAYING FOR THE CONTROL OF BLIGHT OF THE SUGAR BEET

H. C. Young[1]

It is difficult to estimate the annual loss incurred by Cercospora leaf blight of beets. The disease has been present in our fields almost since beet growing started. More than 30 years ago experiments on dusting and spraying

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were conducted and the results indicated that the disease could be controlled. However, it was stated in these earlier conclusions that the cost was probably too great to warrant such recommendations.

A general survey indicates that the disease has gradually increased until at present it is causing distinctive losses. Formerly it was estimated that actual losses occurred in 1 year out of 5 or 7 years but during the past 5 years leaf spot has caused losses each year.

In 1938 many growers of northwestern Ohio decided that if they were to remain in the beet growing business, blight would have to be controlled. Consequently a series of dusting and spraying tests were arranged. Bordeaux and several of the fixed coppers were used. The results are given in Table 1.

Table 1.—Spraying and dusting of sugar beets at Ralph Watson farm at Old Fort, Ohio, 1938. The spray plots were on resistant beets. Tons and sugar per acre and percentage of blight. Applications - 7/13, 7/22, 8/12.

Materials	Yield per acre	Increase over check	Sugar	Purity	Sugar per acre	Increase over check	Gain over check at 4¢ sugar	Blight
	Tons	Tons	%	%	Lbs.	Lbs.		%
Sprays								
Bordeaux 8-12-100	22.93	3.35	16.0	84.6	6310	1580	$63.20	5.0
Basic Copper Chloride	21.09	1.51	16.0	83.8	5652	922	36.88	5.0
Cupro-K	22.73	3.15	15.4	83.2	5819	1089	43.56	8.0
Basicop	24.81	5.23	15.0	81.4	6053	1323	52.92	10.0
Check. No treatment	19.58	—	14.8	81.7	4730	—	—	60.0
Dusts								
Basic Copper Chloride	20.23	2.72	15.2	82.9	5098	1178	47.12	20.0
Cupro-K	20.11	2.62	17.2	82.9	5715	1795	71.80	30.0
Basicop	21.92	4.42	15.4	82.4	5567	1647	65.88	25.0
Tribasic	21.48	3.98	14.6	83.8	5297	1377	55.08	25.0
20-80 Copper-lime	22.19	4.69	14.0	80.9	5028	1108	44.32	30.0
Check. No fungicide	17.50	—	14.0	80.1	3920	—	—	70.0
Average dust plots	21.20	3.70	15.3	82.6	5341	1421	$56.84	
Cost of 3 applications							4.65	
						Net gain	$52.19	

The results of the 1938 series were very favorable and indicated that the increases were well within the economic range.

Many growers did not wait for the outcome of our tests but went ahead on a regular dusting or spraying schedule. Their returns were also on the profit side of the ledger. The general conclusions gained from the 1938 program were (1) that yield was increased 1.5 to 2 tons per acre, (2) that the sugar content of the beet was increased about 1.5%, and (3) that the purity was raised significantly.

The results of these 1938 tests were so favorable that a very large percentage of the acreage was treated in 1939. In arranging our own series we began the study of timing, quantity of dust or spray to use, methods of

application, and types of materials. This study required a large acreage of beets, which was generously supplied by Ralph Watson at Old Fort and the Great Lakes Sugar Company at Findlay and Elmore. The chemical tests, which were very extensive, were handled by the Great Lakes Company in their Fremont factory.

The first applications in general were applied on early beets on July 5. Power machines were used for both sprays and dusts. All copper materials were used at a uniform metallic content and all concentrations were about the same as the 20-80 copper-lime dust. The results are shown in Tables 2 to 6.

The results of the 2 years spraying tests indicate that a 4-6-100 Bordeaux controls very well and that the use of substitute materials is scarcely warranted.

Leaf spot in the Old Fort area was very severe in 1939. There was an abundance of rain until July 1 and the remainder of the season was quite dry. It was a surprise to us that the disease continued in such severity. It may be a general indication that we can expect severe blight almost every season. The control with dusting was successful, even better than with spraying. You will note from the tables that leaf spot was better controlled by spraying, yet dusted beets gave slightly higher yields. Either sprays cause more injury or it is not necessary to have so complete control of the disease.

Table 2.—Spraying of sugar beets at the Ralph Watson farm, Old Fort, Ohio - 1939. Tons of beets, sugar per acre and percentage of blight, 3 applications - 7/5, 7/27, 8/16

Spray materials	Number beets in .01 acre sample	Average weight per beet	Yield per acre	Increase over comparable check	Sugar content	Purity	Sugar yield	Increase over comparable check	Increase in returns computed @ 4¢ sugar	Blight Sept.9 % dead leaf area
		Lbs.	Tons	Tons	%	%	Lbs.	Lbs.		
Bordeaux 6-8-100	158	2.31	18.25	6.02	15.4	83.9	4716	1949	$77.96	5.0
Bordeaux 3-6-100	144	2.37	17.05	4.82	14.0	82.9	4005	1238	49.52	10.0
Check	146	1.70	12.23	—	13.6	83.2	2767	—	—	85.0
Brown Cupric Oxide 2#	151	2.20	16.65	4.42	14.6	84.5	3908	1141	45.64	12.0
Brown Cupric Oxide 1#	155	2.02	15.65	3.42	15.3	84.6	4050	1283	51.32	16.0
Copper Oxychloride Sulfate 2#	154	2.02	15.60	3.37	14.7	85.0	3898	1131	45.24	5.0
Tribasic 2#	140	2.18	15.30	3.07	14.5	82.6	3665	898	35.92	10.0
Check	146	1.70	12.23	—	13.6	83.2	2767	—	—	85.0
Basicop (tribasic) 2#	134	2.43	16.30	4.07	13.2	80.5	3464	687	27.88	10.0
Basic Copper chloride 2½#	138	2.68	18.55	6.32	15.2	84.1	4742	1975	79.00	8.0

Average of 4 replicates. 2.2 tons necessary for significance.

Table 3.--Dusting and spraying of sugar beets, Elmore, Ohio, 1939. Tons of beets, sugar per acre and percentage of blight. Applications made 7/14, 8/7 and 8/24

Materials used	Weight per beet	Tons per acre	Increase over comparable check	Sugar content	Purity	Sugar per acre	Increase over check	Gain computed @ 4¢ sugar	% dead area from blight
	Lbs.		Tons	%	%	Lbs.	Lbs.		
Bordeaux 6-8-100	1.77	18.9	2.3	16.0	77.0	6048	139	$ 5.56	5.0
Bordeaux 3-6-100	1.70	19.3	2.7	16.0	80.0	6176	267	10.68	12.0
Tribasic Copper Sulfate 2 lbs. Flour 6 lbs. Tergitol 50 c.c. Water 100 gal.	1.92	19.7	3.1	15.8	79.0	6225	316	12.64	10.0
Basicop 2 lbs. Flour 6 lbs. Tergitol 50 c.c. Water 100 gal.	1.80	18.5	1.9	16.4	81.0	6068	159	6.36	15.0
20-80 copper-lime dust	1.84	18.8	2.2	16.2	80.7	6091	182	7.28	60.0
Basic copper chloride 2½ lbs. Flour 6 lbs. Tergitol 50 c.c. Water 100 gal.	1.80	17.45	.85	15.2	77.1	5305	-604	-24.16	10.0
Check - Average of duplicates	1.56	16.6	—	17.8	83.5	5909	—	—	85.0

Harvest September 24, 1939, which was too early and results are not significant.

Table 4.—Dusting of sugar beets at the Ralph Watson farm, Old Fort, 1939. Tons of beets, sugar per acre and percentage of blight. 4 applications - 7/5, 7/26, 8/16, 8/30

Dust materials	Number beets in .01 acre sample	Average weight per beet	Yield per acre	Increase over comparable check	Sugar content	Purity	Sugar yield	Increase over comparable check	Increase in returns computed @ 4¢ sugar	Blight Sept. 9 % dead leaf area
		Lbs.	Tons	Tons	%	%	Lbs.	Lbs.		
Copper-lime, 20-80	142	2.64	18.80	6.57	15.2	87.9	5023	2256	$90.24	20.0
Copper-lime-bentonite 20-60-20	162	2.33	18.90	6.67	15.8	89.5	5345	2578	103.12	18.0
Check	146	1.70	12.23	—	13.6	83.2	2767	—	--	85.0
Copper-lime-flour 20-60-20	164	2.11	17.35	5.12	16.0	88.5	4913	2146	85.84	15.0
Tribasic 8# Talc 42# Flour 15#	144	2.60	18.70	6.47	14.6	83.4	4553	1786	71.44	20.0
Brown Cupric Oxide 6# Talc 44# Flour 15#	172	1.97	17.0	4.77	16.0	94.7	5152	2385	95.40	20.0
Check	146	1.70	12.23	—	13.6	83.2	2767	—	--	85.0
Basic copper chloride 9# Talc 41# Flour 15#	158	2.10	16.67	4.44	15.4	89.3	4585	1818	72.72	10.0

Average of 4 replicates. 1.8 tons necessary for significance.

Table 5. Dusting of sugar beets on Ralph Watson farm, Old Fort, Ohio, 1939. Tons and sugar per acre. 3 applications applied at night

Material	Yield per acre	Increase over comparable check	Sugar content	Purity	Sugar per acre	Increase over check	Gain at 4 cent sugar
	Tons	Tons	%	%	Lbs.	Lbs.	
20-60-20 copper-lime-flour	11.37	2.31	14.6	81.8	2715	758	$30.32
Check. No treatment	9.06	—	13.4	80.6	1957	—	—
Spraycop	10.12	1.97	14.6	82.9	2449	713	28.52
Cuprocide GA	9.27	2.02	15.2	83.2	2343	728	29.12
Check	7.25	—	13.2	84.4	1615	—	—
Copper Oxalate	8.82	1.57	14.4	82.5	2099	484	19.36
Tribasic	10.76	3.51	14.2	80.9	2575	960	38.40

Late planted beets on sandy soil, 75% stand. 1.6 tons necessary for significance.

Perhaps the largest amount of our work centered around the use of monohydrated copper sulfate-hydrated lime dusts and substitutes. The results indicate that the copper-lime combinations may be a trace more effective than the fixed coppers but they must be applied at night or when the foliage is wet. The fixed coppers may be applied any time when dusting conditions are favorable. Dusting at night is not an agreeable practice and many times cannot be done satisfactorily. A comparison of these two general types of copper when applied during the night and during the day is given in Tables 6 and 7.

The results obtained in this comparison are interesting. Slightly higher yields were obtained from night dusting with most of the materials but this apparent difference becomes insignificant when statistics are applied. The only reason it can be pointed out at all is that the results from chemical tests indicate that slightly more copper adhered to the leaves through rains when the applications were made on wet foliage.

In this work about 35 pounds of dust were used per acre. This amount seemed adequate when the distribution was uniform. A power machine, covering 12 rows, had to be kept in A-1 working order.

Perhaps much more work needs to be done in determining the timing of the applications. The results given in Table 8 are for early and late beets.

The tonnage results given in the table are not too significant. However, after a detailed study of the plots during the growing season, results warrant the following conclusions. The first application should be made about 40 days after blocking and thinning. This means that four applications at not over 10-day intervals are required for early beets andperhaps three applications would be sufficient for late planted beets.

Table 6.—Dusting of sugar beets at the Ralph Watson farm, Old Fort, 1939. Comparison of day and night dusting. Tons of beets and sugar per acre and percentage of blight.

Dusting materials and time of dusting	Number beets in .01 acre sample	Average weight per beet	Yield per acre	Increase over comparable check	Sugar content	Purity	Sugar yield	Increase over comparable check	Increase in returns computed @ 4¢ sugar	Blight Sept. 9 % dead leaf area
		Lbs.	Tons	Tons	%	%	Lbs.	Lbs.		
Check	146	1.70	12.23	—	13.6	83.2	2767	—	—	85.0
Tribasic 8#) Talc 42#) Day Flour 15#)	153	2.04	15.62	3.39	15.4	87.7	4140	1373	$54.92	20.0
Tribasic 8#) Talc 42#) Night Flour 15#)	144	2.60	18.70	6.47	14.6	83.4	4553	1786	71.44	20.0
Brown Cupric Oxide 6#) Talc 44#) Day Flour 15#)	156	2.03	15.85	3.62	15.6	88.5	4376	1609	64.36	40.0
Brown Cupric Oxide 6#) Talc 44#) Night Flour 15#)	172	1.97	17.00	4.77	16.0	94.7	5152	2385	95.40	20.0
Basic Copper Chloride 9#) Talc 41#) Day Flour 15#	144	2.55	18.40	6.17	15.2	90.9	5084	2317	92.68	25.0
Basic Copper Chloride 9#) Talc 41#) Night Flour 15#)	158	2.10	16.67	4.44	15.4	89.3	4585	1818	72.72	10.0
Check	146	1.70	12.23	—	13.6	83.2	2767	—	—	85.0

Average of 3 replicates. 2.1 tons necessary for significance.

Table 7.—Dusting of sugar beets, Findlay, Ohio. Tons of beets, sugar per acre and percentage of blight. 4 applications - 7/13, 8/4, 8/17, 8/28

Material used	Yield per acre	Increase over comparable check	Sugar content	Purity	Sugar per acre	Increase over check	% dead leaf area from blight Sept. 9
	Tons	Tons	%	%	Lbs.	Lbs.	
20-80 copper-lime dust	16.1	6.0	16.0	84.2	4338	1803	40.0
20-60-20 copper-lime-flour	15.6	5.5	15.6	83.1	4044	1509	35.0
20-60-20 talc	14.9	4.8	16.7	85.2	4140	1605	32.0
Check	10.1	—	15.4	81.5	2535	—	80.0
Basicop (day)	14.5	4.4	16.4	85.2	4052	1517	25.0
Basicop (night)	14.5	4.4	15.6	85.8	3886	1351	20.0
Cupro-K (day)	11.7	.4	16.3	85.0	3242	180	25.0
Cupro-K (night)	14.1	2.8	15.7	83.2	3683	621	20.0
Check	11.3	—	15.9	85.2	3062	—	60.0
Brown Cupric (day)	14.5	3.2	15.5	84.1	3780	718	25.0
Brown Cupric (night)	15.0	3.7	15.5	83.6	3886	824	20.0
Copper Oxychloride Sulfate	13.5	—	15.6	82.3	3466	404	20.0

2 acre plots.

Table 8.—Spraying of sugar beets to determine timing of applications, 1939, on the Ralph Watson farm, Old Fort, Ohio. Tons of beets, sugar per acre and percentage of blight.

Bordeaux 6-8-100 applied on	Number beets in .01 acre sample	Average weight per beet	Yield per acre	Increase over comparable check	Sugar content	Purity	Sugar yield	Increase over Comparable check	Increase in returns computed @ 4¢ sugar	Blight Sept. 9 % dead leaf area
		Lbs.	Tons	Tons	%	%	Lbs.	Lbs.		
Early Beets										
July 5	156	1.91	14.90	2.67	13.4	80.6	3218	451	$18.04	20.0
July 5; 27	164	1.85	15.20	2.97	15.8	84.2	4044	1277	51.08	5.0
July 5; August 16	156	2.00	15.65	3.42	14.6	83.6	3820	1053	42.12	35.0
Check	146	1.70	12.23	—	13.6	83.2	2767		—	85.0
July 27	168	1.88	15.80	3.57	16.2	87.1	4459	1692	67.68	12.0
July 27; August 16	168	1.89	15.90	3.67	15.6	85.5	4242	1475	59.00	12.0
August 16	160	1.63	13.05	0.82	14.0	82.1	3000	233	9.32	75.0
July 5,27;Aug. 16	Discarded because of use for roadway.									
Late Beets										
Check	146	1.70	12.23	—	13.6	83.2	2767	—	—	85.0
July 5,27; Aug. 16	158	2.31	18.25	6.02	15.4	83.9	4716	1949	77.96	5.0
Check	158	1.40	10.88	—	12.3	83.1	2224	—	—	85.0
July 5	162	1.58	12.80	1.92	12.6	82.9	2674	450	18.00	20.0
July 5;27	148	1.70	12.55	2.95	15.0	87.3	3287	1490	59.60	5.0
July 5; August 16	148	1.73	12.85	3.25	14.6	86.4	2842	1045	41.80	35.0
Check	158	1.21	9.60	—	11.4	82.1	1797	--	--	85.0
July 27	154	1.72	13.25	3.65	12.8	82.6	2802	1105	44.20	12.0
July 27; August 16	174	1.63	14.20	4.60	14.8	86.0	3615	1818	72.72	12.0
August 16	174	1.30	11.30	1.70	14.4	82.4	2681	884	35.36	75.0

Soil variation influenced the results of this series. 1.8 tons necessary for significance.

Cost of Dusting

This will vary, depending upon the cost of labor and materials. Considerable commercial dusting has been done in the beet area at the following figures.

Total for 3 applications
Copper-Lime Dust

3 applications at 75 cents per acre	$2.25
Monohydrated copper sulfate, 20 lbs. @ 9 cents	1.80
Hydrated lime, 80 lbs. at 1/2 cent	.45
Total cost	$4.50
Flour, 15 lbs. at 2 cents adds	.30
	$4.80

Fixed Copper-Lime Dust

Fixed copper (based on 50% metallic), 12 lbs. at 15 cents	$1.80
Talc, 73 lbs. at 3/4 cents	.55
Flour, 15 lbs. at 2 cents	.30
3 applications at 75 cents per acre	2.25
Total	$4.90

These costs are on the basis of 33-1/3 pounds of dust per acre per application. The figures are based on 1939 costs and there is no guarantee that the cost of application or the materials will be the same in the future.

Spraying costs are slightly higher, due to the time factor. Materials for spraying are cheaper.

General Summary

The results for the 1938 and 1939 seasons indicate clearly that it pays to spray or dust beets. The tonnage increases range from 20 to 50 percent and there is an increase in sugar content of about 1½ percent.

Leaf spot was serious in both seasons and the untreated plots showed about 90 percent of their leaf area dead on September 1.

In general, dusting gave slightly higher yields than did spraying, although the latter gave somewhat better leaf spot control.

The copper-lime-flour combination, 20-60-20, was slightly superior in sticking and leaf spot control to any of the fixed copper compounds. However, this increase was scarcely significant.

The fixed coppers, particularly the chloride and sulfate types, can be used effectively in daytime dusting.

A STUDY OF SPACING EFFECTS WITH TWO VARIETIES OF SUGAR BEETS ON A HIGH AND LOW LEVEL OF SOIL FERTILITY
(Demonstration Paper)

By A. W. Skuderna and C. W. Doxtator[1]

A study on two varieties of sugar beets, one a high tonnage, the other a sugar variety was undertaken in 1938 at Rocky Ford, Colorado, on a soil of high and low levels of fertility.[2] The results of the study indicated that the tonnage variety responded to increased applications of fertilizer, the largest increase coming from a 600 pound per acre application of commercial fertilizer. On the other hand, applications of commercial fertilizer beyond 200 pounds per acre depressed the sugar per acre yields of the sugar variety. It was concluded, that information was needed as to whether a variety was a strong or weak feeder, in order that an adequate program of soil fertilization for sugar beets might be developed.

Results reported herewith are based on a study which is an outgrowth of last year's work. In this study it was strongly suggested by the results obtained that variation in spacing distances between beets in the row, combined with varying rates of fertilizer applied might uncover more information than were but one spacing interval employed. To that end, the present study was planned.

Materials and Methods

The soil type on which this study was conducted was classified as Rocky Ford fine sandy loam. In the fall of 1938, a 12 ton coating of cattle manure was applied per acre immediately prior to fall plowing. The field was worked down to a good seed bed in late March and planting was made during the second week in April. Two domestic varieties of sugar beets were used, one being a "sugar" variety and the other a "tonnage" variety. Both of these varieties were of the same uniformity as to type as those used in the 1938 tests.

The commercial fertilizer used was 4-16-4, at rate of 500 pounds per acre, applied with the seed at time of planting.

The plat arrangement was fully randomized and of such layout as to permit unbiased evaluation of interactions between varieties, treatments, and rates of fertilizer application. Each treatment was replicated seven fold, the plats being four rows wide and 100 feet long. The distance between rows was 20 inches. Fifty-six plats were included in the study.

The beets were thinned to a distance of 10 and 15 inches in the row and were grown to maturity under irrigation. The beets were harvested on a competitive basis and analyzed for sucrose by the usual cold water digestion method. The results in all cases represent an average of the seven replications. The data were analyzed by the variance method.

1/Manager and Plant Breeder, respectively, Beet Seed Operations, American Crystal Sugar Company.

2/L. A. Hurst, A. W. Skuderna, C. W. Doxtator: A Study of High and Low Levels of Soil Fertility Response to Two Varieties of Sugar Beets. Journ. of Am. Soc. of Agron. 31:Page 649-652.

Results

The results of this study are shown in Table I. The statistical tabulation of interactions is shown in Table II.

Table I.—Results of Spacing Distance Between Beets, and Rate of Fertilizer Application With Sugar Beets. Rocky Ford, Colorado, 1939

	Sugar Variety		Tonnage Variety	
	Fertilized	Not Fertilized	Fertilized	Not Fertilized
	Tons Beets Per Acre			
10" Spacing	18.79	18.14	25.53	23.62
15" Spacing	17.12	14.42	19.45	18.25
Required for Significant Difference	1.52**			
	Percentage Sucrose in the Beet			
10" Spacing	17.04	17.16	14.64	14.66
15" Spacing	16.87	16.62	13.87	14.79
Required for Significant Difference	.57**			
	Pounds Sugar Per Acre Yield			
10" Spacing	1417	6338	7468	6919
15" Spacing	5781	4801	5413	5370
Required for Significant Difference	422**			

Table II. Values of F. Applied to Yield, Percentage Sucrose, and Sugar Production Per Acre for Two Spacing Distances, and Fertilizer Application Applied to Two Varieties of Sugar Beets

	Tons Beets Per Acre F	Percentage Sucrose F	Pounds Sugar per Acre F
Blocks	7.42**	5.97*	10.81**
Spacing x Blocks	N.S.	N.S.	N.S.
Varieties	84.07**	321.16**	8.58**
Spacing	72.00**	N.S.	78.09**
Amounts	10.48**	N.S.	7.07
Varieties x Spacing	8.87**	N.S.	5.21*
Varieties x Amounts	N.S.	N.S.	N.S.
Spacing x Amounts	N.S.	N.S.	N.S.
Varieties x Spacing x Amounts	11.31**	13.15**	11.35**

*Significance beyond 5% point.
**Significance beyond 1% point.
N.S. No significant difference.

Discussion

Spacings Disregarded

In the test, the "tonnage" and "sugar" varieties behaved true to designation. The "tonnage" variety outyielded the "sugar" variety 4.57 tons per acre for the no fertilizer treatment and 4.53 tons for the fertilizer treatment. 1.52 tons was the calculated amount required for a significant difference.

In percent sucrose, the "sugar" variety was 2.16% higher than the unfertilized "tonnage" variety and 2.70 percent higher sucrose than the "tonnage" variety fertilized compared to .57% required for significance.

In yield of sugar per acre, the tonnage variety produced 342 more pounds for the fertilized treatment and 575 more pounds for the unfertilized treatment respectively, than was produced from the "sugar" variety. A difference of 422 pounds was required for significance.

Spacings considered

For the 10 inch thinning, the "tonnage" variety (fertilized) produced 6.08 tons more beets than the 15 inch spacing. For the same treatment, the "sugar" variety produced but 1.67 more tons beets than from the 15 inch spacing. Evidently, the "sugar" variety utilized more efficiently the increased plant food in the wider spacing than did the "tonnage" variety. For the unfertilized treatment, the "tonnage" variety spaced 10 inches apart outyielded the 15 inch spacing by 5.37 tons. For the "sugar" variety the difference was 3.72 tons in favor of the 10 inch spacing.

An increase in distance of spacing generally depressed the percent sucrose in the beet. In general, the percent sucrose was .32 and .36 higher for the "tonnage" and "sugar" varieties respectively for the 10 inch spacing compared to the 15 inch spacing.

The increases in sugar per acre yield were likewise strikingly in favor of the closer spacing interval. For the "tonnage" variety the fertilized 10 inch spacing outyielded by 1055 pounds the 15 inch spacing. Similarly, the unfertilized 10 inch spacing outyielded its wider spaced comparison by 1549 pounds. For the "sugar" variety, there was a marked reduction in difference of sugar per acre yield for the fertilized treatment, the difference being but 636 pounds per acre in favor of the 10 inch spacing. This compares with 1537 pounds for the same comparison for the unfertilized treatment.

Conclusions

Under the conditions of this test, the effectiveness of fertilization and closer spacing of beets in the row is again demonstrated.

There was noted however, for the "sugar" variety, a marked increase in efficiency of utilizing additional plant food, when the interval of spacing was increased. This increase however was not sufficient to overcome the reduced yield of sugar per acre obtained from the wider spacings.

HARVEST SAMPLING STUDIES WITH FIVE VARIETIES OF SUGAR BEETS
(Demonstration Paper)

C. W. Doxtator[1]/

In the past, harvest data has often been obtained from variety tests prior to the normal harvesting period for the purpose of determining which varieties are the more productive.[2]/ When data taken at preharvest dates indicate significant differences between varieties, it has been commonly expected that these differences would be maintained up to and including the harvest made on the normal harvesting date.

In the increase of elite and breeders stock of sugar beet seed at Rocky Ford, Colorado, there is a timely need for additional information on the performance of new breeding strains so that only the best may be increased. Since in this area the latest safe date for fall planting for seed production is September 5th, it is not possible to obtain yield data of the normal harvest date (approximately October 10) on varieties for evaluation purposes. If however, harvests made prior to September 5th are found to give similar information to harvests made at the normal harvest date, the earlier harvests are the more valuable, since information is obtained when needed.

From certain preharvest data obtained from variety tests conducted in 1937 at Rocky Ford, Colorado, it was indicated that the prediction of yields of varieties from the preharvest date to the normal harvest date might be erroneous. Since much of the previous work done in preharvest sampling was not sufficiently replicated to give a reliable estimate of error, the present study was undertaken.

The purpose of this study was to determine what yield relationship varieties bear to each other at different harvest dates during the fall season, and what use could be made of advance information in the shaping of a seed increase program.

Materials and Methods

Five commercial varieties were used, four of which were of domestic origin. Three of these were classified as intermediate type, one was a tonnage type and one was a sugar type. The varieties were planted in fifty foot, four row plots in four replications, for each of seven harvest dates and for each of the two years, 1938 and 1939. The tests for each year were arranged in a split plot experimental design; the varieties being arranged so that the greater precision would be obtained between varieties at each date of harvest, thus allowing the lesser precision to fall in the different harvest dates where differences were likely to be large. All plots were planted in 20 inch rows, and a thinned stand of 10 inches between beets obtained. All harvests were made by the competitive method, and yields were recorded on a single beet basis. Of the seven harvest samplings made, four were considered as made at preharvest dates, two were normal harvest dates and the last sampling was made at a post harvest date. All harvest data was statistically analyzed by the Analysis of Variance Method.

1/Plant Breeder, American Crystal Sugar Company

2/American Beet Sugar Company—Research Department—Annual Reports 1919-1929 inclusive.

Experimental Results

Since the data obtained on the five varieties in test is in reality a study of rate of growth, the data are presented in graphic form as growth rate curves. The following graph shows relative yields in pounds weight per beet, percent sucrose and pounds sugar per beet respectively. The growth rate curves are an average for the two years 1938-1939.

In Graph No. 1 a fairly consistent rank in weight per beet is shown for the five varieties. The slight changes in rank seen in the September 26 harvest are small enough to be within limits of experimental error. The three leading varieties, numbers 1, 2 and 3 of the August 23 harvest are, for the last two harvests not significantly different between each other, but are different from varieties No. 4 and 5; these being the low ranking varieties at the first harvest date. The reduction in weight on the October 20 and November 1 harvests is accounted for in lack of irrigation during the month of October for both years. In percent sucrose, there is a consistent performance for all varieties at all harvest dates. Changes in rank are all well within experimental error. For pounds sugar per beet, the performance of the varieties at the seven harvest dates indicates that the relative performance of the varieties over the harvesting period does not greatly differ. However, in the case of varieties No. 1 and 5, the reversal of form shown on the September 26th harvest does approach significant proportions. At all other dates however, differences in yields of these two varieties are not significant.

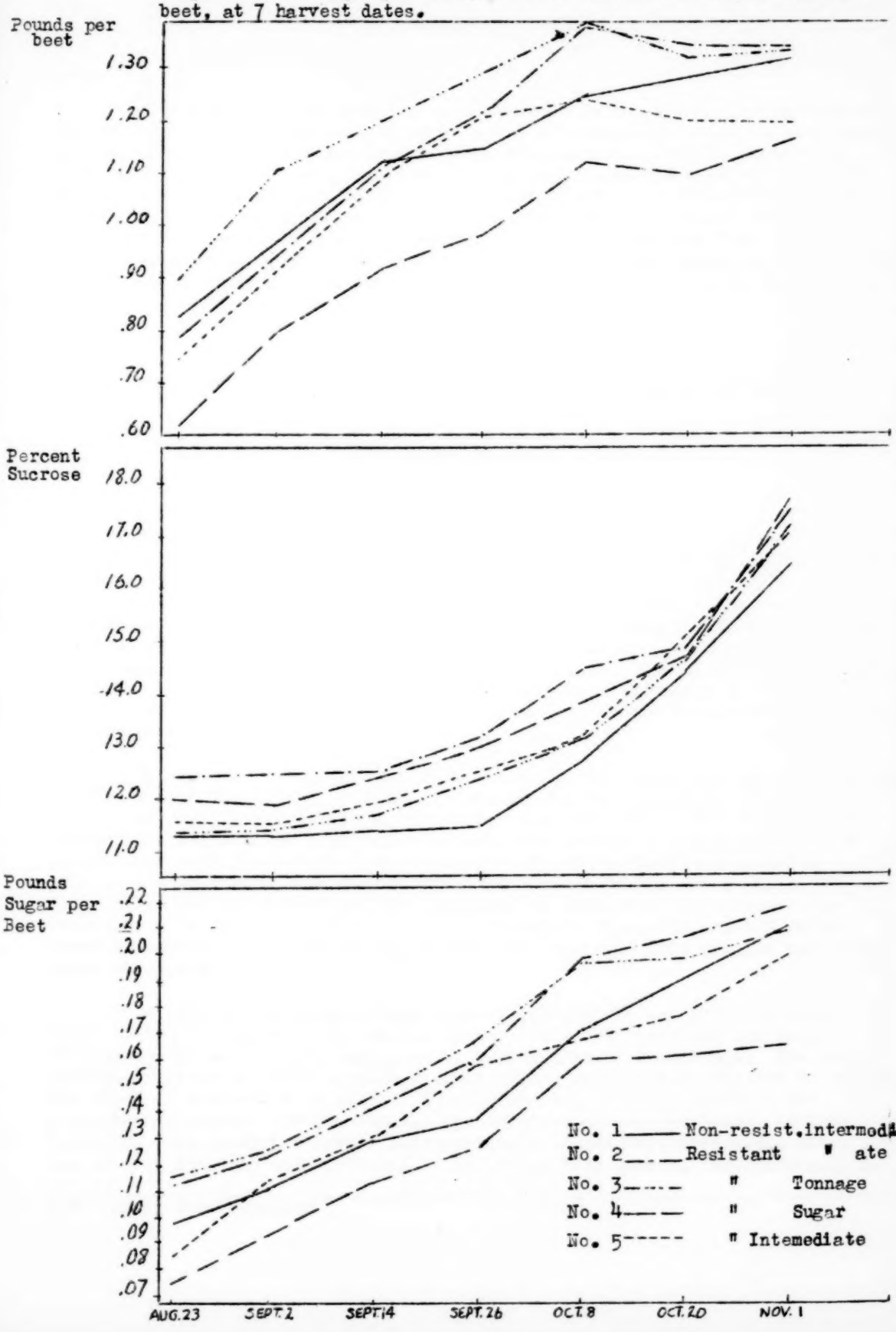
Since, as mentioned previously, the latest date for obtaining information in time for use in evaluating varieties to be planted for fall annual seed production at Rocky Ford is September 5th and the normal beet harvest date approximately October 10, it is of interest to compare the results obtained for these two dates. In Table I are given the data obtained for the harvest samplings made on September 2 and October 8th.

Table I. Comparison of 5 Varieties at the Two Harvest Dates, September 2 and October 8.

Variety	Weight Per Beet Lbs.				Percent Sucrose				Lbs. Sugar Per Beet			
	Sept. 2	Rank	Oct. 8	Rank	Sept. 2	Rank	Oct. 8	Rank	Sept. 2	Rank	Oct. 8	Rank
No. 1	.98	2	1.25	3	11.47	5	12.75	4	.110	4	.168	3
No. 2	.96	3	1.38	2	12.40	1	14.50	1	.124	2	.196	1
No. 3	1.10	1	1.39	1	11.58	4	13.20	3	.125	1	.195	2
No. 4	.80	5	1.12	5	11.84	2	13.92	2	.094	5	.159	4
No. 5	.94	4	1.24	4	11.61	3	13.20	3	.113	3	.168	3
Sign. Diff. (19:1)	.17		.18		.73		.70		.026		.027	

It will be observed that in weight per beet, variety No. 4 was lower than the other 4 varieties at both harvest dates. At both dates of harvest, Variety No. 2 was higher than No. 4, a result significantly demonstrated only at the October 8 harvest. In percent sucrose the relative performance of all varieties was quite similar at both harvests. In pounds sugar per beet varieties No. 2 and 3 rank above the other varieties at both dates, but significantly so only on the later date. Variety No. 4 was consistently low in yield.

Graph No. 1 - Weight per beet, percent sucrose and weight sugar per beet, at 7 harvest dates.



Conclusions

The data obtained from the seven harvest dates of the five varieties tested over the two year period, shows a fairly consistent relative performance for these varieties over the entire harvesting period. Certain changes in rank in different harvests do occur, but in most cases these are well within the limits of experimental error. Consequently, adequate evidence of interaction of varieties and dates of harvest is lacking. It appears therefore, that in this area it is a safe procedure to use data obtained from the preharvest samplings, in place of the normal date of harvest sampling data for the evaluation of varieties for use in determining which varieties to increase for seed.

THE USE OF SOIL MOISTURE DETERMINATIONS TO REGULATE IRRIGATION PRACTICES IN COMMERCIAL BEET FIELDS

(Demonstration Paper)

J. E. Coke and E. I. Hechman[1/]

Since the inception of irrigated agriculture, irrigations have been regulated largely by the appearance of the growing crop. In the production of sugar beets in California this method is not sufficiently accurate, in most instances, to permit maximum utilization of soil fertility, light, etc. Furthermore, many attempts to increase production of sugar beets by fertilization failed because sufficient soil moisture was not available to support the additional plant growth. Therefore, to make full use of soil fertility, light, and other growth factors and to make possible increased yields by increased fertilization, soil moisture must be maintained at proper levels throughout the growing period.

The amount of moisture in soils available to plants can now be accurately determined (1,2,3,4,5), so that irrigation may be regulated, thereby preventing an excessive or deficient supply of soil moisture. The technique of determining for a large commercial acreage, the amount of water available to plants in a soil throughout the growing period and regulating irrigation practices accordingly have been difficult. Because of the far-reaching importance of proper irrigation and the inability of most growers to secure the necessary soil moisture information, the Spreckels Sugar Company has undertaken to develop a program to supply this information. This program has been under way since 1937.

In 1939 the Spreckels Sugar Company selected 85 key growers, from whose fields it secured soil samples at intervals not exceeding ten days throughout the major sugar beet growing period (May to September). The percentage of water in these samples was determined and the data charted to obtain the trend of extraction of water. Each grower was advised regarding the irrigation procedure for his field. The moisture equivalent (water holding capacity), necessary for proper interpretation of moisture percentage data, was secured for each soil previous to the irrigation season. Moisture equiva-

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1/Spreckels Sugar Company

lent, and permanent wilting percentages determined for most soil types in the Spreckels Sugar Company supply area in 1937 showed the permanent wilting percentage of the large majority of these soils to be approximately one-half the moisture equivalent. Therefore, only moisture equivalents have been determined on soils in recent studies and the permanent wilting percentage of those soils has been calculated by dividing the moisture equivalent by 2.

The soil sampling procedure for a field was as follows:

(1) Samples at random were obtained in a field until the soil types representative of the majority of the field were located.

(2) In each representative soil area a stake was driven near the head, the middle, and the foot of an irrigation run. Samples for moisture equivalents and for all moisture determinations were secured within a few feet of these stakes.

(3) To obtain soil samples for moisture determinations two holes were bored near each stake at each date of sampling and dirt from the two holes composited for the following depths:

0 to 6 inches - Sample discarded
6 to 24 " - Sample No. 1
24 to 42 " - Sample No. 2
42 to 60 " - Sample No. 3

There were, therefore, three moisture determinations for each location or nine for each field at each date of sampling. The moisture percentage for each depth was plotted on charts, on which the permanent wilting percentage and moisture equivalent of that soil had been previously plotted. A copy of this chart was kept in a convenient place on the ranch for the grower to observe. By this means the grower was able to visualize the extent of penetration and the rate of extraction of soil moisture from his soil.

Soil samples were obtained with soil tubes 7/8" in diameter, 5 feet in length, equipped with cutting point head and a twelve pound hammer.

The usual laboratory method of determining the moisture percentage of soils requires 24 hours of oven drying. It was found essential that moisture percentages be known very soon after the samples were secured in order (1) to maintain the interest of the cooperator, and (2) to give timely advice regarding irrigation procedure. Various rapid methods of determining soil moisture were tested. The Alcohol Method developed by G. J. Bouyoucos of the Michigan Agricultural Experiment Station (6 & 7) was found most efficient and sufficiently accurate for the type of work involved. Wooden cases, 25" wide, 15" high and 6" deep were fitted with balance scale, cups for burning soil, shield to protect cups while burning, alcohol supply, and cleaning equipment, and were provided each field superintendent of the Spreckels Sugar Company. With this equipment it was possible to secure and make the required nine soil moisture determination for a field in approximately one and one-half hours. It was found impractical to use the equipment in the field because of the effect of wind on the scale, therefore the moisture determinations were made in a sheltered place.

A study of the 85 soil moisture charts of fields under irrigation control in 1939 and the resulting sugar beet yields show the real value of the project. Not only has the technique of interpreting the trends of soil moisture supply been improved, but growers are recognizing the importance and value of this project and are willing to use the moisture information as a guide in their irrigation program.

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Section B. Genetics, Breeding, Seed and Varieties - Chairman: A. W. Skuderna

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LIST OF CHARACTERS AND GENE SYMBOLS REPORTED FOR THE SPECIES BETA VULGARIS L.

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Introduction

A list of characters and their gene symbols is presented for the species Beta vulgaris L., in so far as these have been reported in literature or have been communicated to the writer. Only those characters are included for which breeding data, meager in some instances, have led to a reasonable factorial interpretation.

The gene symbols recorded in table 1 follow the terminology suggested by the worker who originally described the character or the one who supplied the factorial analysis. The character description is limited to the obvious gene effects which were indicated in the original reference sources.

Several characters, such as those dealing with root size, foliage size, and sucrose formation have not been included in the present list. For information regarding the possible genetic basis of these quantitative characters the reader is referred to the review by Schneider (11). Attention is also called to the omission, from table 1, of several factors (L_1, L_2, A_1, A_2, O, B and F) which according to the earlier view of Kajanus (3) condition the shape of the root. In a later paper, Kajanus (4) points out that root shape is a difficult character to classify into basic root types because of the existence of intermediate forms.

So far one linkage group including nine genes has been established. These linked factors are collectively designated as the R group. Eight other factors appear to be inherited independently of the R linkage group. No linkage data are available for the four remaining factors, included in the present list. The available information regarding linkages is given in connection with the description of the main gene effects.

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Table 1.--- List of characters and gene symbols reported for Beta vulgaris L. 1/

Character type	Description of gene effect	Present symbol	Authority
	Red color series 2/		
Foliage and root color	Red hypocotyl and crown-bud color. Basic authocyan factor.	R 3/	Kajanus, B.(5) Keller, W.(6)
	Red striped petioles. Termed "red-top".	R^t	Keller, W.(6)

Table 1 (continued)

Character type	Description of gene effect	Present symbol	Authority
	Absence of anthocyan pigment. With y gives green hypocotyl and crown-bud type. With intense sunlight exposure yellow pigment may develop.	r	
	Yellow color series		
	Yellow pigment produced in presence of r. Color extended to petioles, larger leaf veins and root epidermis. With R color is red. Linked with R group of factors.	Y 4/	Keller, W. (6)
	Yellow pigment produced but restricted to epidermis of root and sometimes part of the flesh. Linked with R group of factors.	Y^r	do.
	Absence of yellow pigment.	y	
	Colored leaf. Colored areas on leaf blades occur as irregular sector-like blotches. Pigment intensified by sunlight and fails to develop in darkness. Spots red with R and yellow with r. Linked with R group of factors.	Cl	Owen, F. V.
	Small veins of leaf red in presence of R and yellow with r. Large veins in leaf petioles are free from pigment with Cv but strongly colored with Y. Linked with R group of factors.	Cv	Deming, G. W. Owen, F.V.
	"Trout" leaf. Colored spots smaller than in case of colored leaf Cl. Spots red with R and yellow with r. Pigment not intensified by sunlight and develops in the dark. Linked with R group of factors.	Tr	Owen, F. V.
Chlorophyll variations	Albino seedlings. Absence of normal chlorophyll. Lethal. Probably independent of R linkage group.	w	Stewart, D.
	Variegated foliage. A mosaic of white and normal green sectors. Linked with R group of factors.	v1	Owen, F. V.
	Variegated cotyledons. Light green to normal green sectors. Probably independent of R linkage group.	v2	Stewart, D. Abegg, F. A.
	Variegated foliage and root flesh. Yellow to normal green sectors. No linkage data available.	v3	Abegg, F. A.
	Virescent. Seedlings yellowish but turn green in later stages of development. No linkage data available.	vi	Stewart, D.

Table 1 (continued)

Character type	Description of gene effect	Present symbol	Authority
Dwarf types	Crinkled foliage. Plant size reduced. Linked with R group of factors.	cr	Stewart, D.
	Flaccid leaf. Vigor of plant markedly reduced. Probably independent of R linkage group.	f	do.
	Nana plants. Leaves thick and leathery. No linkage data available.	n	do.
	Miniature. Greatly reduced plant size. Lethal. Probably independent of R linkage group.	m	Abegg, F. A.
Fertility	Self-fertility. Dominant factor. Probably independent of R linkage group.	S^f	Owen, F. V.
Growth habit	Annual habit or rapidly blooming types. Dominant. A possible variation of the B locus which conditions a bolting tendency but not a strictly annual habit is described by Owen, F. V., Carsner, E., and Stout, Myron (10). Linked with R group of factors.	B	Munerati, O. (9) Abegg, F.A. (1)
	Biennial or vegetative habit.	b	
Foliage venation	Semiparallel venation as contrasted with normal pinnate type. Probably independent of R linkage group.	pl	Abegg, F.A. (1)
Foliage shape and area	Newly formed leaves at end of vegetative period markedly reduced in leaf area, narrow lanceolate in shape. No linkage data available.	re	Zavitsky, V.E. (13)
Root epidermis	Black root skin. Probably independent of R linkage group.	bl	Munerati, O. & T. Costa (8) Vilmorin, J.L. (12)
	Russett root skin. Probably independent of R. linkage group.	ru	Owen, F.V. Owen, F.V.
Disease resistance	Partially dominant major factor which conditions high curly-top resistance. Linked with R group of factors.	C	Abegg, F. A.
	Susceptible	c	

1/ In form, table 1 is similar to that used by Hutchinson and Silow (2) in presenting the subject of gene symbols for use in cotton genetics.
2/ The term "series" implies multiple allelomorphs.
3/ Symbols of dominant genes are capitalized and those of the recessives are in small letters.

4/ The symbol G (gelb) was used by Kajanus (5) to describe a yellow root character which may have been a similar genetic type for which Keller (6) used the symbol Y. Lindhard and Iverson (7) adopted Kajanus' symbols of R and G for red and yellow color types. Vilmorin (12) substituted the symbol J (jaune) for that of G. Owen in correspondence expresses the viewpoint that Y is a factor for extension of pigment rather than one which produces yellow pigment. Y causes much more pigment to be developed but does not determine whether the color is red or yellow.

THE THREE DIMENSIONAL QUASI-FACTORIAL EXPERIMENT WITH THREE GROUPS OF SETS FOR TESTING SUGAR BEET BREEDING STRAINS

H. L. Bush[a]

The recent trend toward breeding and production of "Home Grown" sugar beet seed has emphasized the problem as to how the breeding strains may be adequately tested in order to insure the maintenance or improvement in performance of the commercial varieties which evolve from these strains.

The ordinary commercial variety of sugar beets is extremely heterozygous, not unlike the commonly known varieties of corn (excluding present-day hybrids), or the human race. When a plant breeder is attempting improvement in resistance to disease, yielding ability, sugar content, shape of root and crown, and perhaps other characters, he is certain to be dealing with large numbers of strains regardless of whether the family or inbreeding mode of attack is followed.

The fact that our soils are very heterogeneous is generally recognized. When the number of strains being tested becomes quite large, the soil variations are necessarily increased due to the larger area covered by the test. It is obviously desirable to remove the effects of soil variations upon yield and other characters as nearly as possible.

Fisher 2/[b] introduced the randomized scheme of plot technique, basing his theory on the complete block setup i.e., where each replication includes all varieties. Yates 6/7/8/ has more recently evolved the scheme whereby incomplete blocks are used as the basis. These incomplete blocks are made up by arranging the strains in a series of blocks, each of which contains only a small number of the strains being tested. The arrangement is such that a variety variance can be calculated which is free from block effects and an error variance obtained for testing the significance of variety means.

There have been several types of designs evolved covering all phases of agronomic tests. Goulden 3/4/ has discussed the various types of designs and worked out examples to demonstrate the calculations involved for each type. He recommends the use of the Three Dimensional Quasi-Factorial method, designed by Yates, where the number of strains to be considered is 216 or more.

Day and Austin 1/ have applied this three dimensional scheme in testing the germination of 729 varieties of pines. Their experiment was planned so that the varieties were subjected to as many different block effects as possible, even to the point of introducing watering differences between blocks. The corrected average number of days from watering time to germination for each

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a) Statistician, Great Western Sugar Company
b) Figures in brackets refer to Literature Cited, Page 116

progeny was 4.6 days, while the actual average range was from 3.3 to 5.9 days. This is evidence that the design did eliminate the effects of plot differences upon the average values for the watering. They found their test to be 2½ times as precise as if the ordinary randomized block design had been used.

This scheme appears especially desirable for sugar beet breeding work because it provides for a large measure of local control as a result of the inclusion of a small number of plots within the block, between which variance is removed; at the same time providing for the testing of a large number of varieties or strains in one test.

The initial requirement of a Three Dimensional Quasi-Factorial test is that the number of strains to be tested shall be a perfect cube. In this case 343 strains of sugar beets or $(7)^3$ strains were tested. Therefore, 7, varieties made up one block and 49 blocks constituted one complete replication. The basic arrangement of the strains in sets in cubical form showing the position of the key numbers (uvw) of the strains in the cube is shown in Figure 1:

From this cube the three groups of sets may be written down. The groups result from slicing the cube in the directions indicated by the arrows in Figure 1. Each strain is indicated by the numbers uvw with vw constant in group X, uw constant in group Y, and uv constant in group Z. No attempt will be made here to demonstrate the manner in which the sets are written out since Goulden [3/4] has already published a complete 3 x 3 x 3 scheme.

For this test there were two replications of each group. Thus, there were two blocks composed of the strains as designated in each set in the cube. Strains were randomized within each block with the blocks being randomized within the group. A different randomized arrangement was used by the second replication of the groups. The randomization was further completed by randomizing the groups over the field.

It is possible to distribute the blocks over the whole field without regard to group or replication but in order to facilitate handling of seed at planting time and enable one to make observations covering a complete replication at one time, it was deemed better in this case to keep one complete group together. The blocks were so arranged as to have each group or replication in as compact a form as possible. The distribution of the blocks within the groups over the field is shown in Figure 2.

The usual care and precautions for conducting an experiment were employed throughout the season using the block as the unit for standardization of cultural treatments.

Since Goulden [3/4] and Day and Austin [1] have worked out complete problems using this scheme, it is not within the scope of this paper to show methods or steps in calculating the data. The results obtained, in comparison with those obtained in other tests, are shown in Table 1. The data are presented with the precision of the various Quasi-Factorial tests represented in percentage of the precision of the randomized block test taken as 100 per cent. The formulae for these precision calculations as used here were taken from Goulden [5]

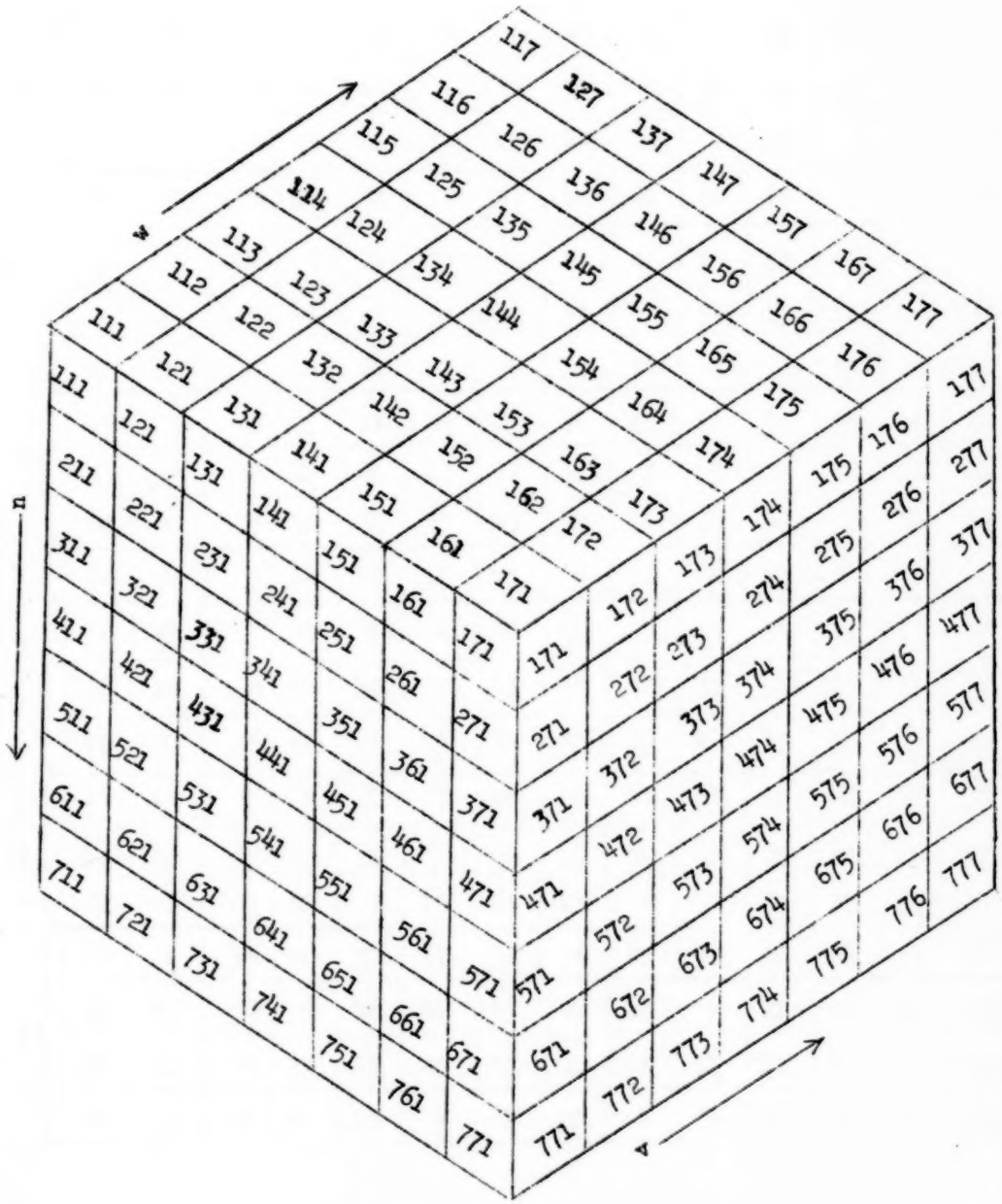

Figure 1 - 7 x 7 x 7 cube illustrating the principle involved in writing out the sets for a three dimensional Quasi-Factorial experiment

F I E L D P L A N

With block numbers as they appear in Field

Z	27	36	19	47	3	24	6	43	9	2	35	23	17	22
	44	20	28	21	25	1	16	30	5	32	39	37	13	46
	14	45	31	12	41	33	10	49	29	7	4	8	26	38
X	19	41	33	24	28	32	23	48	40	18	15	11	42	34
	16	3	26	1	45	40	43	48	11	15	38	17	21	2
	20	35	29	46	7	39	42	37	27	34	13	18	4	44
	25	36	47	10	22	12	6	31	49	5	8	30	9	14
Y	17	1	20	39	11	48	49	26	25	28	34	16	36	18
	33	5	46	41	40	12	27	30	7	14	4	15	21	37
	42	45	13	43	35	23	19	32	31	10	47	6	38	44
X	48	22	3	24	29	19	25	9	22	8	29	24	3	2
	6	44	7	43	31	4	46	41	2	23	27	12	17	15
	26	18	36	14	35	8	13	45	42	30	1	28	34	9
	49	20	16	40	21	11	38	32	10	47	37	33	5	39
Z	13	14	31	6	9	29	26	44	48	34	7	42	45	2
	47	38	23	22	36	1	25	16	24	46	28	12	11	17
	18	8	41	10	3	19	21	15	4	49	30	35	39	20
Y	14	4	15	21	37	17	1	5	40	32	37	42	33	27
	44	33	34	5	46	41	49	40	12	7	27	18	39	11
	26	36	45	13	43	48	35	32	28	31	10	47	6	38
	25	3	22	20	23	9	2	30	8	29	19	16	42	24

Figure 2

Table 1 - Precision of other designs in per cent of the complete randomized block test used as standard

Test	Precision in per cent of Randomized Block Design
Quasi-Factorial - Examples, Yates	126 to 157
" " - " , Goulden	186 to 187
Incomplete Randomized Block, G.W.S. Co.	
Per cent sugar	134
Weight	141
Two dimensional, two groups of sets, G.W.S.Co.	
Per cent sugar	131 & 194
Weight	168 & 183
Two dimensional, three groups of sets, G.W.S.Co.	
Per cent sugar	196
Weight	262
Three dimensional, three groups of sets, G.W.S.Co.	
Three replications, Per cent sugar	228
" " Weight	206
Six replications, Per cent sugar	296
" " Weight	268

These results show the two dimensional with three groups of sets and the three dimensional with three groups of sets to be considerably more efficient than the other Quasi-Factorial schemes, all of which are highly efficient when compared with the complete randomized block. The two comparisons of the three dimensional plan show that the degree of efficiency is greater where the number of replications is increased.

The chief criticism of any of the Quasi-Factorial schemes is that the labor involved in planning and calculating is somewhat laborious, but the increased efficiency should be well worth the few days extra time necessary to apply the corrections. All results when presented are in the form of average plot values corrected in accordance with the relationship of the strain to the performance of other strains which occur in the same blocks with this strain. Thus, the effects of variation in soil and treatments are equalized for all strains. The amount of correction applied to the results for any strain may be readily seen by drawing off an average of the raw figures for the strain.

In addition to the high degree of efficiency obtained by this method, the three dimensional scheme with three groups of sets is especially desirable in testing sugar beet strains since the small number of plots within a block tends to make all agronomic work more efficient. Experience has shown that it is extremely difficult to complete one set of operations over one whole replication of a large number of strains within a short enough time to consider it as uniform, especially if some weather changes occur. It is much easier to control irrigations within a small block than over a large number of plots which would constitute a block or replication in the randomized block scheme. Also, from the standpoint of soil variability the smaller block is especially desirable in sugar beet testing work on account of the relatively large plot size necessary for an adequate test. The efficiency value obtained for three replications which is more than twice as large as for the randomized block indicates that we could test twice as many strains and obtain slightly greater accuracy with three replications under this scheme for approximately the same expenditure of land, time, and funds as is necessary where the complete randomized block is

used with six replications. Thus, it would be possible to gain a broader view of the material in the preliminary phases of the breeding work.

The use of the three dimensional plan may be adapted to the degree of accuracy desired and apparently can be used with confidence.

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COMPARISON OF QUASI-FACTORIAL AND RANDOMIZED BLOCK DESIGNS FOR TESTING SUGAR BEET VARIETIES

A. W. Skuderna and C. W. Doxtator 1/

In order to obtain statistically significant differences between varieties or treatments, it is imperative that factors which influence error variance are adequately controlled. This can be accomplished in part through more critical selection of experimental fields, and in part through more efficient plot arrangement. However, experiments involving a large number of varieties or treatments, the size of the replications may become so large that plot variability of the test cannot be efficiently controlled.

In recent years there has been a growing tendency on the part of experimentalists to group classes of data into smaller and more homogeneous subclasses rather than using randomized blocks of larger size and possibly greater

plot variability. As a result, quasi-factorial arrangements have been described by Yates 2/ and Goulden 3/ who reported gains in efficiency ranging from 26 to 57 per cent and 20 to 50 per cent respectively. Le Clerg 4/, employing the two dimensional quasi-factorial design and randomized block design, reported results of tests conducted in 1937 and 1938. In these tests, the relative efficiencies of both types of plot arrangements were compared. Using 36 treatments in the test for control of damping off organisms, the conclusion reached was that the quasi-factorial plot design was more efficient than the randomized block design in some seasons.

The purpose of this paper is to report the results obtained from 11 variety tests with sugar beets, each of which was analyzed as a symmetrical incomplete block experiment, and as randomized block experiment.

Materials and Methods

The eleven variety tests of sugar beets were conducted in the following areas; seven near Rocky Ford, Colorado; two near Alamosa, Colorado and two near East Grand Forks, Minnesota. Four of the tests contained 9 varieties each, four contained 16 varieties each, two contained 25 varieties each and one contained 49 varieties. All tests were conducted during 1939, with the exception of the 49 variety test, which was planted in 1938. Each of the eleven tests were designed as a symmetrical incomplete block experiment. Randomization was practiced on the varieties which were allocated in each set (or block) and blocks were randomized within the replicates.

The percent of efficiency of the symmetrical incomplete block analysis in relation to the randomized block analysis was determined from the mean square for error obtained from each analysis. In Table I is given these percent efficiency figures.

Table I.—Increase or Decrease in Percent Efficiency of the Symmetrical Incomplete Block Design as Compared With a Randomized Block Arrangement of Equal Size in Variety Tests with Sugar Beets

No. Varieties in Test	No. of Tests in average	Average Percent Increase or Decrease		
		Tons Beets	Percent Sucrose	Lbs. Sugar Per Acre
			Rocky Ford, Colorado, 1938	
49	1	+ 25	+ 43	+ 48
			Rocky Ford, Colorado, 1939	
25	2	+ 3	+ 80	+ 5
16	2	- 11	+ 10	+ 10
9	2	- 11	+ 37	- 16
			Alamosa, Colorado, 1939	
16	1	+187	+182	+226
9	1	- 5	+ 23	- 10
			East Grand Forks, Minnesota, 1939	
16	1	- 16	+ 14	- 3
9	1	+ 30	- 8	+ 14

Discussion

The results obtained indicate a loss of precision in the 9 variety tests at Rocky Ford and Alamosa in tons beets and pounds sugar per acre, and a loss in precision in percent sucrose at East Grand Forks by the use of the incomplete block design. In the 16 variety tests a loss of precision was found in tons beets per acre at Rocky Ford and in tons beets and pounds sugar per acre at East Grand Forks. A great increase in precision was observed in the 16 variety test at Alamosa, Colorado. Extremely variable irrigation practice in part accounted for the greater error of the randomized block analysis in this test. In the two 25 variety tests and the 49 variety test at Rocky Ford, increase in precision in tons beets per acre, percent sucrose and pounds sugar per acre was obtained in varying degrees. 5/

Conclusion

From the comparisons of analysis methods herein reported it is indicated that the symmetrical incomplete block design is likely to be less efficient than the randomized block design in tests of 16 varieties or less; and approximately equal to or better than the randomized block design in tests of 25 varieties. In tests of 49 varieties the incomplete block design is likely to be much more efficient than the randomized block design.

1/ Manager and Plant Breeder respectively, Beet Seed Operations, American Crystal Sugar Company, Rocky Ford, Colorado.

2/ Yates, F. A NEW METHOD OF ARRANGING VARIETY TRIALS INVOLVING A LARGER NUMBER OF VARIETIES. (Journ. of Agri. Sci. (England) 26:424-455. 1936.

3/ Goulden, C. H. EFFICIENCY IN FIELD TRIALS OF PSEUDO-FACTORIAL AND INCOMPLETE RANDOMIZED BLOCK METHODS. Canadian Journ. Research (C) 15:231-241. 1937.

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5/ Under the conditions of these tests, leafspot incidence was not a factor. It is therefore not known as to how much bias would be introduced under such conditions in applying the correction factor (which is fundamental to this symmetrical incomplete block method) to variety yields of varying degrees of resistance to leafspot.

THE INDUCTION OF POLYPLOIDY IN *BETA VULGARIS* L. BY COLCHICINE TREATMENT

By F. A. Abegg, Associate Geneticist, Division of Sugar Plant Investigations, Bureau of Plant Industry, United States Department of Agriculture

The plumule region of small sugar beet seedlings was treated, by the single drop method, with colchicine in concentrations of 0.2 and 0.4 percent. The application of colchicine was repeated either four or eight times during successive days. The following selections, designated by current number, were given such meristem treatments:

2241 .... Munerati annual. Low self-fertility.
6499 .... Annual "wild" type from Milpitas, California. Low self-fertility.
2245 .... Plantain foliage venation type. Biennial in bolting character. Low self-fertility.

2323 .... Derived from the Tracy strain 2769-24 highly self-fertile.
3653 .... An inbred strain originally selected from E. Carsner's 286 stock noted for high curly-top resistance. Highly self-fertile.
3521 .... F_2 progeny of hybrid between Munerati annual x Tracy strain, 2769-24. Self-fertile and segregating for the hypocotyl color genes R - r and the bolting factors B - b (annual vs. biennial habit.)

Following the drop treatment seedlings were found to be greatly retarded in growth. Distorted and roughened leaves were formed. In later stages of growth a return to the normal, flatter type of foliage was apparent. At the time of flowering 45 plants of the 92 seedlings treated with colchicine showed, in some of their branches, varying amounts of larger than normal-sized pollen. Some measure of the effect of colchicine is indicated by the results from pollen examination. It was found that approximately 65 percent of the 45 plants with large pollen developed at least one, and usually several branches whose flowers had large pollen grains in a high proportion. The pollen size of the remaining 47 plants was very similar to that of the normal 1 n grains produced by untreated controls from the same strains.

Cytological observations of pollen mother cells from a limited number of branches which formed high percentages of large pollen grains showed that in general doubling of chromosomes had occurred. The number of chromosomes at Telophase I varied from 17 to 19. Untreated plants with pollen of normal size gave the expected haploid number of 9 chromosomes at the same stage.

Heteroploid plants were obtained in the progenies derived from the colchicine treated seedlings of strains 2241, 3521, and 3653. The presence of such heteroploids, in relatively large percentages, was also noted in the progenies from the crosses of treated plants of strains 2241 x 6499 and 6499 x 3521, respectively.

The conclusion that the offspring from treated plants were heteroploid in nature was based on data concerning stomatal size, pollen diameter, degree of pollen sterility, as well as chromosome number determinations in certain cases. The indications were that one class of heteroploids approximated the tetraploid or 4 n chromosome number of 36. A second class apparently was of the 3 n or triploid type.

The heteroploids derived from colchicine-treated plants of the annual strain 2241 showed no consistent difference in size of plants when compared to the parental diploid stock. However, two heteroploid progenies secured from strain 3521 and the inbred line 3653 differed from the offspring of comparable untreated controls in several respects. These differences were in germination rate, seedling size, leaf shape, flowering habit and amount of seed set.

In addition to the drop method of treatment, seed of the Munerati annual strain 2241 was soaked in 0.4 percent colchicine for periods of 8 hours, 1, 2 and 3 days. Appreciable percentages of plants were found, from all such treatments, some branches of which developed flowers with a high proportion of large pollen. It was evident from previous experience with the meristem treatment that increased pollen size was associated with a doubling of chromosomes. Therefore, it is probable that the plants which were grown from colchicine-treated seed and showed large pollen would give rise to heteroploid offspring.

INDICATIONS OF POLYPLOIDY IN SUGAR BEETS INDUCED BY COLCHICINE

By Ernst Artschwager, Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, United States Department of Agriculture.

In attempting to produce polyploidy in sugar beets three types of treatment were employed: (1) soaking of seed, (2) application of colchicine to crown buds, and (3) treatment of mature floral parts. The first had for its object a change of chromosome number in the cells of the vegetative growing point of the mature embryo of germinating seeds. By the second treatment an attempt was made to induce chromosome doubling in meristematic cells of the nascent floral axis of second year seedlings. The third type of treatment sought to influence the fertilized egg or the embryo in its initial stages of development.

To bring about a change in the chromosome complex of cells of the growing point of the mature embryo, the seed itself was subjected to the influence of colchicine. Such treatments have been attempted by practically all who are engaged in genetic research with sugar beets, ever since the discovery of the effects of colchicine on plants. The treatment consisted essentially of soaking the dry seed balls in a weak aqueous solution of colchicine for a given period, usually 24 to 48 hours. The method produced apparent results in that the immediate visible effect was very striking, since many of the young seedlings showed thickened hypocotyls and malformed cotyledons and leaves, and on cytological examination exhibited giant cells with a higher chromosome number. Unfortunately, the effect disappeared sooner or later. Newly developed leaves were of the normal type. 1/

In the writer's experiments, two types of seed treatment were used: (1) Treating dry seed balls with an aqueous solution of colchicine and (2) pre-soaking the seed balls in tap water before treatment with colchicine. Minimum length of treatment was 18 hours without pre-soaking and 10 hours when preceded by 24 hours of pre-soaking. While the strength of the colchicine solution was kept constant (0.5 percent), the length of treatment was varied in the different tests. The longer treatments gave a higher number of malformed seedlings, many of which died in the early stages of development. Of those remaining, some apparently outgrew the effects of colchicine while a few continued to develop tissues with changed chromosomal numbers as attested by cytological examination.

In the second type of treatment, the aim was to influence the meristematic cells of the nascent growing point of the floral axis of second-year seedlings. About 500 plants were decapitated at the advent of seedstalk development, care being taken to leave enough of the embedded leaf primordia to assure new vegetative growth. The stumps left after the removal of the leaves were painted over with one-half percent colchicine agar and, to protect the exposed surface from sunlight and flooding during irrigation, small parchment bags were tied over the stumps and left there until new growth had started. Since the treatment was drastic, a number of treated plants failed to recover and died. Others developed new leaves and normal seedstalks and flowers which, however, produced normal pollen and seed. Less than 10 percent of the treated plants produced new leaves with signs of malformation like those of seedlings from colchicine-treated seeds. Since these plants failed to produce seedstalks,

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1/ Rasmusson, J., and Levan, A. Tetraploid sugar beets from colchicine treatment. Beet Breeding Station Hilleshög, Landskrona, Sweden.

they were transplanted to nursery rows and their further development will be followed this coming spring.

As the vegetative growing point consists of many cells and as only a certain number divide simultaneously even under most advantageous conditions, treatments to influence the fertilized egg or the embryo in its initial stages of development should be more promising than the methods just outlined. With this in view, flowers that had opened the day before and also those of an earlier date of anthesis were treated with colchicine. In one set of experiments the flowers were painted over with colchicine agar, while in another set of treatments, lateral branches of the floral axis from which all unopened flowers had been removed were immersed in test tubes of colchicine solution of one-half and one percent strength, respectively. The length of treatment in the immersion experiment varied from one-half hour to four hours. To keep the agar from drying out too rapidly the treated branches were enclosed in parchment bags for a period of 24 hours. The treated material was left on the plants until harvest time. Each lot was collected separately and planted out in nursery rows during July and August. The development of the young seedlings was followed and all plants that appeared from a study of the lower leaf epidermis to be normal were discarded.

It is a well-known fact that plants with a higher chromosome number have larger stomates, and, since it is time-consuming to make a cytological analysis of all individuals, circumstantial evidence gained from a study of the leaf epidermis is sufficient for making preliminary discards. The leaf epidermis is easily stripped and the length of the stomate measured with an ocular micrometer. By this method about 10,000 seedlings were examined in the course of the summer. All plants with stomates measuring less than 35 microns were discarded and individual records were kept of those remaining in the nursery rows. The plants were tested again after an interval of two months and those that had reverted back to normal were removed. In this manner the number of actual or potential "takes" was narrowed down with final eliminations to be made on actual cytological examination of young floral branches when they appear.

NUCLEAR PHENOMENA IN THE POLLEN TUBE OF SUGAR BEETS

By Ernst Artschwager, Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, United States Department of Agriculture

Pollen tubes that have developed on nutrient agar are broader than those that grow in the tissue of the style of the beet flower. This fact has been studied in other plants by Wulff (3) 1/ who found in certain cases that tubes in culture were from five to six times as broad as those in the style. However, other investigators found no difference in appearance of pollen tubes and their nuclei in artificial and natural media.

Sperm nuclei first appear in the pollen tubes of the sugar beet developing on artificial media after the tubes have attained a length of about 50 microns or approximately the combined diameter of two or three pollen grains. The sperms are not always found close to each other and their position relative to the distal end of the tube also varies. The two sperms are easily recognized. Their shape varies from that of a spindle or shallow crescent to that of a sphere. When emerging from the pollen grain they are practically always elongate but may become round later on. Occasionally extra sperm-like bodies,

1/ Numbers in parentheses refer to Literature Cited.

probably resulting from a division of one or both of the sperms while in the pollen tube, have been observed.

The tube nucleus is usually wanting. Its shape in the mature pollen grain is already more or less abnormal, and the degenerative processes are usually completed before the pollen grain germinates. One sees occasionally faintly-staining hollow spheres reminiscent of the degenerating tube nucleus, but these structures are often fixation images of some of the abundant plasmic content of the pollen tube. Earlier studies by the author (1) and observations by Oksijuk (2) showed the presence of a tube nucleus some distance beyond the sperms in pollen tubes growing in the tissue of the style. More recent observations by the author point to the fact that the vegetative nucleus, especially in tubes developing on artificial media, is usually lacking. Degeneration of the tube nucleus and its absence from the pollen tube is not uncommon in other plants and its occurrence in sugar beets is of little significance.

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A COMPARISON OF THREE METHODS OF HARVESTING SUGAR BEET PLOTS

A. W. Skuderna 1/

In plot experiments with sugar beets, it is customary practice with many research workers to weigh as far as practicable all of the beets from the plots for determination of yield. Some investigators remove border rows to reduce border effect, while others ignore it. Some add refinement to the method of plot harvest by harvesting only normally competitive beets. Others endeavor to correct for variations in stand by various means, such as reducing the plot yields to an acre basis using the percent stand as one of the factors in the conversion. Others use the covariance method in adjusting yield to stand, or resort to some other statistical treatment of data calculated to give proper weight to variations in stand so that a valid estimate of yield and its accompanying standard error may be obtained.

There is considerable confusion as to the proper method of harvest to employ. This arises, no doubt, from the fact that no one method of plot harvest will satisfy all conditions. Thus, it has been held by some that

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1/ Manager, Beet Seed Operations, American Crystal Sugar Company.

where effect of treatment is to be determined, the actual yield based on the harvest of all of the beets in the plots is the proper procedure regardless of the resulting stand. There are others however who hold an opposing view, contending that the net effect of treatment can only be determined by holding the stand constant and harvesting the plots on a normally competitive beet basis. 2/ Disagreement also exists as to what constitutes a normally competitive beet, how it is to be selected, and whether its use is justified when the percent stand at harvest drops below a certain point. Some hold that when stands are 85 percent or better at harvest, and are uniform as to distribution in the row, either the normally competitive or actual yield methods of harvest will give equally reliable results. Then there are others who contend that the "normally competitive" method of beet harvest piles up more error in closer spacings of beets than in the wider spaced beets, and that contrary to general opinion, the use of this method of beet harvest in plots of low percent stand increases the error in an opposite direction instead of correcting it.3/

There is general agreement among sugar beet agronomists, that the ideal method of plot harvest exists when at harvest the stands approach perfection or near perfection, namely a full stand. In such cases, the harvest of the entire plot on an actual yield basis is indicated. Just how much these yields would differ compared to those when harvested on a normally competitive basis is a conjecture, since to the writers knowledge no such comparisons have ever been made. However, it would be an interesting study, and one which will need to be fully explored before our knowledge in this direction is as complete as it should be.

Unfortunately, one hundred percent stands do not generally prevail at harvest, due to losses resulting from insect pests, dideases, lax cultural operations, unfavorable climatic conditions and the like. Unquestionably, the actual yield method would be acceptable to any agronomist when stands permit its unrestricted use, as it is fairly well known that in the hands of the untrained or careless worker, the slip shod selecting of normally competitive beets can easily become a travesty upon good judgment because of unreliability of data obtained. Those who have used the normally competitive beet method know the extreme need for exercising of care in selecting beets that are truly surrounded by beets in all four directions. Further, that as stands decrease, it may be necessary to exercise even greater caution in harvesting beets having the necessary requirements of adequate competition.

The writer having been one of a rather small group of investigators early interested in the normally competitive method of beet harvest of experimental plots in this country, did so on the basis of information furnished by well conducted uniformity trials.4/ The percent recovery in yield from adjacent missing spaces was determined, and recommendations for field practice arrived at, as to what was thought a fair procedure in selecting a normally competitive beet. This was done in order that results of far flung

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2/ Brewbaker, H.E. and Dening, G.W. 1935. EFFECT OF VARIATIONS IN STAND ON YIELD AND QUALITY OF SUGAR BEETS GROWN UNDER IRRIGATION. Jour. Agri. Research 50:195-210.

3/ Nuckols, S.B. 1936. THE USE OF ACTUAL AND COMPETITIVE YIELD DATA FROM SUGAR BEET EXPERIMENTS. Jour. Am. Soc. Agron. 28: 924-934.

4/ Immer, F. R. 1932: SIZE AND SHAPE OF PLOT IN RELATION TO FIELD EXPERIMENTS WITH SUGAR BEETS. Jour. Agr. Research 44: 649-668.

variety tests the country over might be placed on a comparable basis when calculating the first and second order interactions between varieties and locality, varieties and years and other required statistical information.5/

It was then recognized that inherently the method had several weaknesses in it, namely, (1) different feeding requirements of light and heavy tonnage varieties and (2) seasons of unequal competition between plants. In some seasons this may be very great, while in others it may be a factor of lesser importance; as for example in the tests to be reported later in this paper. With the development and stabilization of sugar beet varieties of more uniform feeding habits, it no doubt will be possible to study more clearly the normally competitive and actual yield methods of harvest respectively, and determine which method is the more effective one, and the possible limitations of both. Therefore, the critical comparison of these two methods of harvesting plots and interpreting the resultant data therefrom is left for future experimental work. For the present, the purpose of the data presented, is to ascertain the justification of deducting skips in the row from the actual beet containing rows when harvest is made, and reporting the uncorrected data on this basis.

Material and Methods

Two variety tests "A" and "B" were conducted in Rocky Ford, Colorado in 1939 with sugar beets on a silt loam soil of average fertility. The field received an application of twenty tons of manure in the fall, following which it was immediately plowed and winter irrigated. The soil was worked down in early spring to an exceptionally good seed bed and planting was made during the first week in April, with a planting rate of 24 pounds seed per acre. Sixteen varieties were used, these being different for each test with the exception of a standard variety which was common to both. Each test was a five replicate randomized block design, and plots four rows wide and 100 feet long were used. The pre-thinning stands were excellent, it being possible to thin the beets in all of the plots 10 inches apart in the row, the thinned stand approximating 100 percent of the required standard of thinning for each test.

Shortly after thinning, phosphate deficiency symptoms developed, resulting in some loss in stand. The extremely hot and dry season that followed, further aggravated the loss of plants, it being impossible to maintain good growing conditions despite the fact that frequent application of irrigation water was made. In the latter part of the season some losses of beets resulted from fusarium root rot, and from other rots so that by time of harvest the average stand was reduced to 81.7 percent in test "A" with variations in stand by variety ranging from 72 to 91 percent. In test "B", the variations were even greater, the stand by varieties ranging from 48 to 82 percent with 71.5 percent as an average for the test. This made it possible to secure comparison data on a fairly wide range of stands at harvest to test the adequacy or weakness of the method of deducting skips from the harvested row in converting the yields to an acre basis.

The plots were quite free from border effect competition, even though heavy tonnage and light tonnage varieties frequently occurred together in comparison plots lying side by each. This pronounced lack of visual competition had not been previously observed in experimental work conducted in

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5/ Skuderna, A.W. et al. 1938. EVALUATION OF SUGAR BEET TYPES IN CERTAIN SUGAR BEET GROWING DISTRICTS IN THE UNITED STATES. U.S.D.A. Circ. 476, 28 pp., illus.

this area over a period of more than twenty years. Nevertheless, the border rows of each plot were discarded at time of harvest. The beets in the two 100 foot long center rows of each plot were counted, and the percent stand recorded. Three comparison methods of harvest were studied, namely; 1. Competitive beet basis in which beets having competition from beets adjacent on all four sides were harvested; 2. Actual yield basis of all of the beets in the entire 2-100 foot center rows; and 3, deducting the skips due to missing beets in the two harvest rows, and reporting the data, without statistical correction, on the actual number of feet of row containing beets. The data for all three methods are reported on an acre basis in Tables I and II.

Table I. Test "A". Comparison of Three Methods of Reporting Yield Data on Sugar Beets. Rocky Ford, Colorado, 1939.

Variety	% Stand	Method 1	Rank	Method 2	Rank	Method 3	Rank
1	90.8	16.51	8	12.49	10	43.97	1
2	77.2	17.19	5	11.36	12	32.18	3
3	83.2	16.84	6	12.46	11	41.92	2
4	87.5	12.48	16	9.80	15	15.76	16
5	85.8	15.79	11	14.25	4	20.34	14
6	75.8	18.47	2	14.21	5	29.84	4
7	88.0	15.67	12	14.01	6	19.43	15
8	74.8	13.98	14	9.70	16	20.64	13
9	80.5	13.87	15	11.21	13	21.33	12
10	85.8	16.41	9	13.92	7	22.23	7
11	77.8	16.32	10	12.66	9	21.54	11
12	83.2	19.91	1	16.32	1	25.67	6
13	84.3	17.50	4	15.25	2	21.70	9
14	79.8	18.23	3	14.59	3	21.62	10
15	80.2	14.00	13	10.59	14	26.12	5
16	72.0	16.61	7	13.04	8	21.87	8
Average	81.7	16.24		12.87		25.39	
Req.for Sig.	99:1	4.62		4.81		11.07	

Correlation (based on 80 plots for each comparison calculation by covariance method)
Method 1-2 +.727
Method 1-3 +.693
Method 2-3 +.702

Table II. Test "B". Comparison of Three Methods of Reporting Yield Data on Sugar Beets. Rocky Ford, Colorado, 1939.

Variety	% Stand	Method 1	Rank	Method 2	Rank	Method 3	Rank
1	47.6	13.44	16	12.00	15	15.72	15
2	56.0	15.76	9	13.01	12	20.04	11
3	55.8	16.02	6	15.71	4	21.84	6
4	81.5	17.31	4	15.93	3	22.23	5
5	81.2	15.84	8	14.32	7	19.38	14
6	70.2	14.58	15	12.68	13	20.94	10
7	73.3	14.91	13	12.02	14	15.29	16
8	68.0	17.90	3	15.12	6	25.20	1
9	74.0	15.85	7	11.92	16	19.88	13
10	82.2	15.43	10	15.14	5	21.31	9
11	75.7	15.36	11	13.06	11	21.35	8

Table II Continued

Variety	% Stand	Method 1	Rank	Method 2	Rank	Method 3	Rank
12	80.7	15.33	12	14.25	8	20.02	12
13	82.0	18.59	1	16.19	2	23.70	3
14	79.5	18.46	2	16.36	1	24.07	2
15	61.8	14.89	14	13.07	10	21.75	7
16	74.0	16.39	5	13.37	9	22.48	4
Average	71.5	15.95		14.01		20.95	
Req.for Sig. 19:1		3.69		3.02		6.03	

Correlation (based on 80 plots for each comparison) Method 1-2 +.759
Method 1-3 +.379
Method 2-3 +.303

Discussion

Test "A"

In comparing the at harvest rankings, Table I, of the varieties in test "A", there is a similarity in rankings between data reported on basis of methods 1 and 2. Using the minimum level of significant difference required for odds of 99:1 or 3.42 tons, it is seen that in Method 1, varieties 12, 6, 14, 13 and 2 rank significantly higher in order given, than variety 4 which was the lowest in yield.

Reporting the yields on an actual basis Method 2, a yield difference of 3.56 tons was found to be significant, or practically the same as for Method 1. Three varieties, 12, 13, and 14 were found significantly higher yielding than the low variety which in this case was number 8. While the information extracted from this method of harvesting was not as great as from Method 1, the rankings are quite similar.

For Method 3, there is a wide dissimilarity in results obtained with the other methods. Using the minimum significant level required, or, 11.07 tons, varieties 1, 3, 2 and 6 were found significantly higher yielding than the low variety number 4. Varieties 12, 13, and 14, which were found highest yielding by the competitive and actual method of beet harvest did not reach the significantly higher yielding group of Method 3. Further, an examination of these data shows that the yields are disproportionately large, when compared to those reported by either of the other two methods, or when compared to the actual harvested and delivered yield of 13.2 tons of commercial beets from this field.

Comparing the correlations calculated for each of the 3 methods, and holding Method 1 as unity, the differences obtained are not very pronounced. This would seem to indicate that even with stands of beets such as obtained in Test "A", the propriety of deducting skips from the harvested row is at best a questionable procedure.

Test "B"

For Method 1, a barely significant level of significance is reached. The difference of 3.69 tons permits varieties 13, 14, 8 and 5 to outyield the low ranking variety number 8. The average stand for this test was but 71.5 percent compared with 81.7 percent for Test "A". Similarly, the range in stands was much greater, this varying by variety from 47 percent to 82 percent.

Odds of 19:1 were either barely reached or exceeded slightly for the "B" test, whereas in the "A" test odds of 99:1 were demonstrable for each method.

In Method 2, a smaller difference, 3.02 tons, was required for significance. This was due to the removal of a large "block" effect in calculating the data, and was directly attributable to wide range in stands. The number of varieties found significantly higher yielding was somewhat greater, these being 14, 13, 5, 3, 10 and 8, compared with variety number 9.

A difference of 6.02 tons for Method 3, made it possible for varieties 8, 14, 13, 16, 5, 3, 15 and 11 to outyield variety 7. However, the test of significance was on the border line, and therefore the data is subject to questioning and especially so when the correlation calculations are examined.

Comparing the correlations for each of the 3 methods, it is seen that the wide divergence in stand in test "B" resulted in correlations some of which are far out of line when compared with those of test "A". In test "B" the correlation between Method 1 and 3, and 2 and 3 dropped off markedly.

Expressing these data in another way, and using the correlation coefficient as a yardstick of efficiency (correlations squared), the following percentages are obtained.

	Test "A"	Test "B"
Method 1-2	52.9	57.6
Method 1-3	48.0	14.4
Method 2-3	49.3	9.2

The above data are merely illustrative, no attempt being made to prove or disprove that the competitive beet basis or Method 1 should be held as unity or 100 percent.

Conclusion

From the data presented, and under the conditions of these tests, it seems safe to conclude that the method of deducting skips from the actual length of harvested row, leads to distortion of yields and in the main is apt to add to the unreliability of data. This tendency becomes more pronounced as the percent stand at harvest becomes lower.

It seems apparent that either the competitive beet or actual yield harvest of the entire plot is preferable to the deducting of skips where no attempt is made to correct the stands by some acceptable statistical procedure.

A METHOD OF CORRECTING TONNAGE OF SUGAR BEETS FOR VARIATION IN PER CENT STAND[1]

H. L. Kohls[2]

There is an abundance of published data showing that as the number of beets per acre increases the tons per acre increases. It is common knowledge that 25,000 beets per acre evenly distributed gives a higher tonnage than 15,000 beets grown under the same conditions. The exact relationship, however, is not well understood by most research men. Consequently they can not make accurate and consistent corrections in tonnage for variations in per cent stand and erroneous conclusions may be the result. But necessity for comparable stands in experimental work has driven many research men to make some kind of a correction.

Several of these methods have been used quite generally at one time or another with varying degrees of success. One method is based on the assumption that the relationship is linear. The average weight per beet is calculated and multiplied by the desired number of beets per acre to give the pounds of beets per acre. The fallacy here is that the relationship is not linear, as will be pointed out later. Consequently, plots with a poor stand and relatively large beets are given an advantage over plots with a good stand and relatively small beets.

A common method of correcting for variation in stand is to use the total weight of all the beets from the areas of the plot where the stand is good. Some workers, however, prefer the "competitive beet" method. Competitive beets being those surrounded by other beets on all sides at appropriate distances as imposed by the experiment. Actual yield and competitive beet methods were studied critically by Nuckols(3)[3] who states that he does not endorse either method. There are instances, he further states, where actual yield should be used and other instances where competitive yields seem to be preferred.

One of the relatively new methods of correcting for variation in stand, as given by Snedecor(4), is based on covariance and is an improvement over some of the older methods.

The purpose of this paper is to present a practical and reasonably accurate method of correcting tonnage of sugar beets for variation in per cent stand where the distribution of the beets on the plot is fairly uniform.

Material and Methods

Two sources of data were used to study the relationship between tonnage and per cent stand in sugar beets. The first was in 1936 sugar beet variety test at East Lansing, Michigan. The second was data reported by Brewbaker (1) in 1937.

Thirty varieties at East Lansing were grown in three-row plots 26.6 feet long and the entire middle row only was harvested. Each variety was re-

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1. Contribution from the Farm Crops Dept. Michigan Agricultural Experiment Station, East Lansing, Michigan, and the Division of Sugar Plant Investigations, U. S. Dept. of Agriculture, cooperating.
2. Research Assistant.
3. Figures in parenthesis refer to "Literature Cited".

plicated 10 times. Variety effect was eliminated by taking the deviation of each plot from the mean of the variety to which the plot belonged. A second degree curve, $y = a + bx + cx^2$, was then calculated from these deviations as the writer believed, from previous work, that the relationship between stand and yield was curvilinear rather than linear. It was expected that one or two extreme deviations might have too great an influence on the position of the ends of the curve but when compared with the curve from Brewbaker's data such proved not to be the case.

The data reported by Brewbaker were used also because they were the average of three years, rather than one, and the beets were grown under entirely different conditions; each plot was thinned to a definite per cent stand. These per cent stands covered a wide range, 11 to 110 based on 28,512 as 100 per cent, and were uniformly distributed along the curve, not grouped near the middle of the curve as was the case with the East Lansing data.

Presentation of Data

The two curves (figure 1) are strikingly similar even though the beets were grown under very different conditions. One curve is above the other, however, and indicates that the growing conditions at East Lansing in 1936 were superior to the average in 1934, '35 and '36 in Colorado. These curves are correct mathematically for the data used but are incorrect agronomically. The equation, as previously stated, is $y = a + bx + cx^2$ in which y = yield and x = per cent stand. The calculated values from the Colorado data are; $a = 3.688$, $b = .224$ and $c = .001$. If we make the per cent stand zero, $x = 0$, the equation becomes $y = 3.688$. In other words, when the per cent stand of beets on the plot is zero we have 3.688 tons per acre. This discrepancy may be explained, at least in part, by the difficulty in getting accurate tonnage data from small plots with poor stands.

If we assume that beets growing four feet apart have no competition with each other and that when there is no competition between beets the tonnage decreases directly as the number of beets decreases, the relationship between stand and yield is a straight line and a correction for the discrepancy in the curves can be made. This correction was made by drawing a straight line from 11 per cent stand, about equal to four foot spacing between plants, to zero. The fact that the curves in the very low per cent stand did not fall where they should, theoretically, does not seriously impair the practical value of these curves in correcting tonnage for variation in per cent stand, because the differences between the curves as they should be and as they are, are so small.

These curves illustrate very clearly that there is a definite relationship between per cent stand and tonnage in sugar beets and that the relationship is curvilinear even though the beets were grown in different environments. The two curves being as similar as they are, may be considered to be different environment-level variants of one basic relationship. This being the case, then other curves representing other levels of environment may be obtained from this basic relationship.

The data from Colorado was used to calculate the six curves shown in figure 2. These curves vary from the original only as the environment-level is superior or inferior to the original environment for sugar beet production. Environment includes all factors which influence tonnage such as natural variation in soil, fertilizer, cultural method, moisture and etc. Tonnage within

an environment varies only as the number of beets or per cent stand varies.

The practical use of these curves may be seen by an example. A plot has a 30 per cent stand and yields 10.29 tons per acre. What would the plot yield if it had an 80 per cent stand? Look up 30 per cent in figure 2 and follow the ordinate down to the actual yield of the plot, 10.29. The curve on which 10.29 is located is the "environment" in which this plot was grown. Follow this curve to the ordinate headed 80 per cent. The tonnage at this point is 15.26 which is the yield that may be expected without any change in the growing conditions of the beets. Another plot may have a yield of 10.0 tons with a 110 per cent stand. Follow the ordinate of 110 to the curve on which 10.00 is located. Then at the ordinate headed 80 per cent the corrected yield will be found as 10.17 tons per acre. The actual yield and the actual per cent stand of each plot is used to find the environment in which the plot was grown. Then any per cent stand and its corresponding tonnage may be chosen. Thus, in an experiment which involves many varieties or many treatments and each replication within a variety or treatment having a different per cent stand, all plot yields can be adjusted to the average per cent stand of all the plots or to any per cent stand desired. All plots are, therefore, made comparable insofar as per cent stand is concerned. For convenience in correcting field data 250 curves such as those shown in figure 2 were calculated and put in table form. A part of this table is shown in table 1.

This paper is given as a progress report and not as a final report. It is intended to present an idea which has practical value but further study should be made to determine more accurately the true relationship between stand and yield in plots with a low per cent stand. Also, in the data used, the maximum yield was obtained with about 26,000 beets per acre and as all the other environmental levels were calculated from the basic curve they all have the maximum yield with about 26,000 beets per acre. There is evidence (2) and (5) that where growing conditions are exceptionally good, more than 26,000 beets give the maximum yield while in very poor growing conditions less than 26,000 beets per acre give the maximum yield. Studies should be made to determine if the maximum yield always is with 26,000 beets or whether it varies with the environmental conditions. For average conditions, however, where the tonnage ranges from 5 to 20 tons and the stand is fairly uniform over the plot but the plots vary from 40 to 100 in per cent stand this method of correcting tonnage for variation in per cent stand is practical and fairly accurate.

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Table 1. Tons of sugar beets at various percent stand and environment (curve number) levels

Percent stand	10	20	30	40	50	60	70	80	90	100	110
No. of beets per acre	2,851	5,417	8,554	11,120	14,256	17,107	19,958	22,810	25,661	28,512	31,363
Curve No.											
10	.40	.57	.69	.79	.87	.94	.99	1.02	1.03	1.02	1.00
20	.80	1.13	1.37	1.57	1.75	1.88	1.97	2.03	2.06	2.05	2.00
30	1.20	1.70	2.06	2.37	2.62	2.82	2.96	3.05	3.09	3.07	3.00
40	1.61	2.26	2.74	3.15	3.49	3.76	3.95	4.07	4.12	4.09	4.00
50	2.01	2.83	3.43	3.94	4.36	4.69	4.93	5.09	5.14	5.12	5.00
60	2.41	3.40	4.12	4.73	5.23	5.63	5.92	6.10	6.18	6.14	6.00
70	2.81	3.96	4.80	5.52	6.11	6.57	6.91	7.12	7.21	7.16	7.00
80	3.21	4.53	5.49	6.31	6.98	7.53	7.89	8.14	8.24	8.19	8.00
90	3.61	5.09	6.17	7.19	7.85	8.45	8.88	9.15	9.27	9.21	9.00
100	4.02	5.66	6.86	7.89	8.73	9.39	9.87	10.17	10.30	10.24	10.00
110	4.42	6.23	7.55	8.67	9.60	10.33	10.85	11.19	11.32	11.26	11.00
120	4.82	6.69	8.23	9.46	10.47	11.27	11.84	12.20	12.35	12.28	12.00
130	5.22	7.36	8.92	10.25	11.34	12.21	12.83	13.31	13.38	13.31	13.00
140	5.62	7.92	9.61	11.04	12.22	13.14	13.82	14.24	14.41	14.33	14.00
150	6.02	8.49	10.29	11.83	13.09	14.08	14.80	15.26	15.44	15.35	15.00
160	6.43	9.06	10.98	12.62	13.96	15.02	15.79	16.27	16.47	16.38	16.00
170	6.83	9.62	11.66	13.41	14.83	15.96	16.78	17.29	17.50	17.40	17.00
180	7.23	10.19	13.35	14.19	15.71	16.90	17.76	18.31	18.53	18.43	18.00
190	7.63	10.75	13.04	14.98	16.58	17.84	18.75	19.32	19.56	19.45	19.00
200	8.03	11.32	13.72	15.77	17.45	18.78	19.73	20.34	20.59	20.47	20.00
210	8.43	11.89	14.41	16.56	18.32	19.72	20.72	21.36	21.62	21.50	21.00
220	8.84	12.45	15.09	17.35	19.20	20.65	21.71	22.37	22.65	22.52	22.00
230	9.24	13.02	15.78	18.14	20.07	21.59	22.70	23.39	23.68	23.54	23.00
240	9.64	13.58	16.47	18.92	20.94	22.53	23.68	24.41	24.71	24.57	24.00
250	10.04	14.15	17.15	19.73	21.81	23.47	24.67	25.42	25.24	25.59	25.00

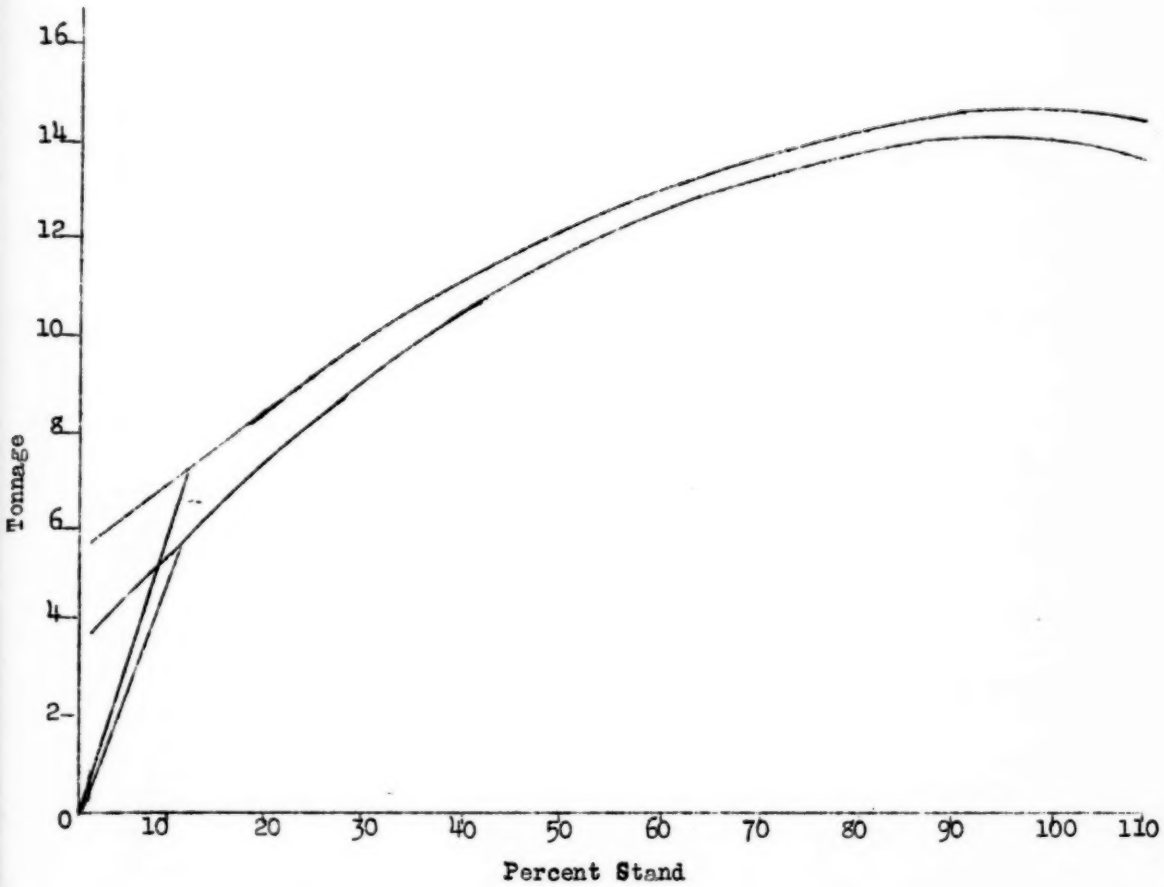

Figure 1. There is a definite curvilinear relationship between tonnage and percent stand of sugar beets even though the beets are grown in different environments. Upper curve is from data of beets grown in Michigan and lower curve is from data of beets grown in Canada.

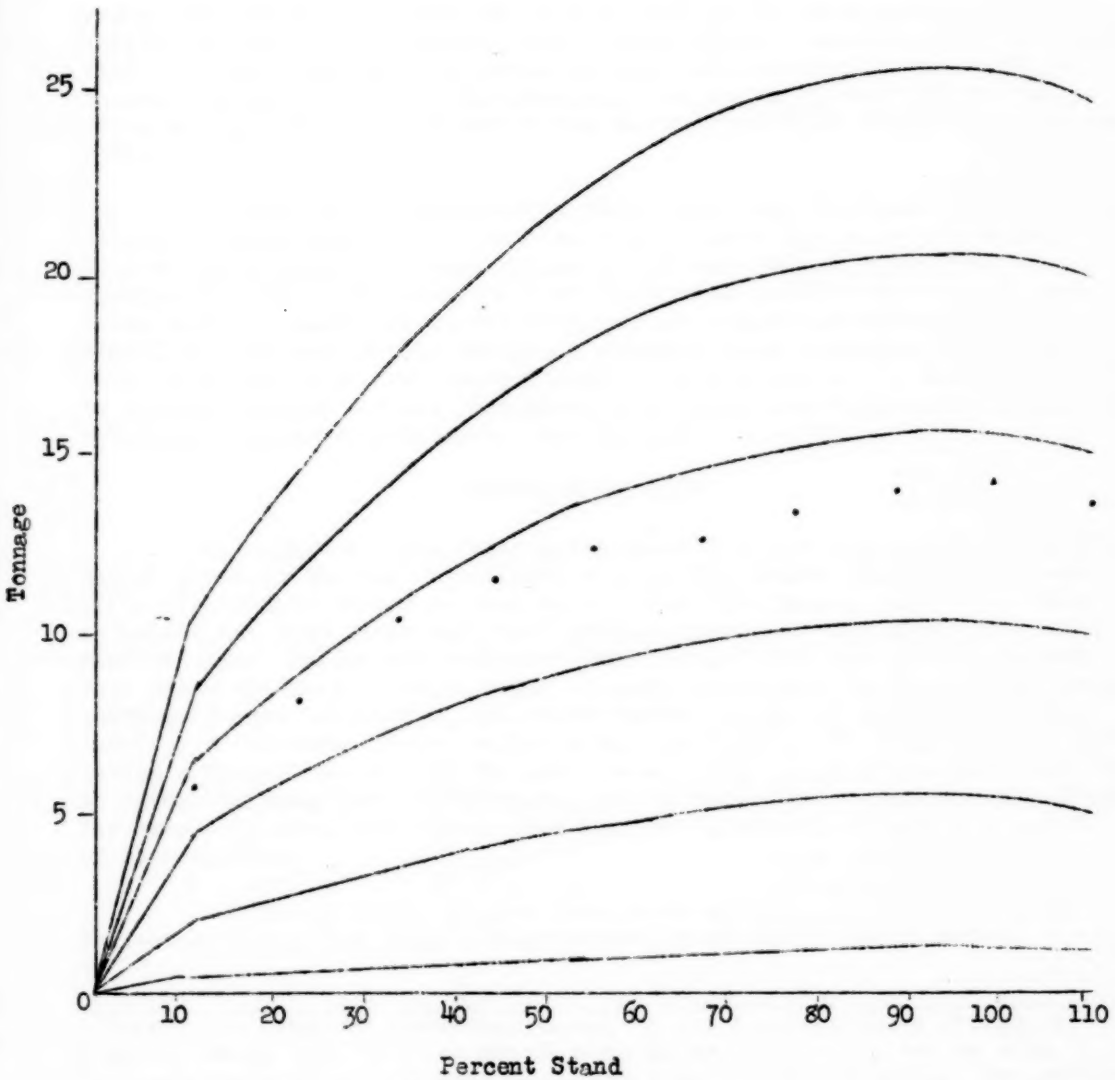

Figure 2. Each environment is represented by a curve which shows the tonnage when the percent stand of beets is varied. The dotted curve is the original data from which the other six curves were calculated.

SUGAR-BEET POLLEN GERMINATION IN RELATION TO ENVIRONMENTAL CONDITIONS

By Ernst Artschwager, Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, United States Department of Agriculture.

In the domestic production of sugar-beet seed, low viability has in certain years in one district or another presented a serious problem in this rather new enterprise. The low quality seed 1/ is characterized by a failure of embryo development. Field observations, together with consideration of weather records and anomalous environmental conditions, have not, in the absence of recognizable abnormalities in the floral structures, revealed the factors concerned in the interference with normal seed development.

In 1936, pollen germination tests with sugar beets at Fort Collins, Colorado, under rather hot, dry conditions showed that a large number of free-blooming plants produced pollen either very low in viability, or sterile 2/. These observations took on special significance when it was found that the seed crop in Colorado in that season had extremely low viability, the seed yields being, in general, below average. Since the data, although extensive, covered only a limited period, it seemed advisable to conduct further studies throughout a blooming season to determine general relation of pollen viability to seed quality.

EXPERIMENTAL WORK

Fall-planted sugar beets being grown for seed production in experimental plots at the New Mexico Agricultural Experiment Station were used. Fifty plants were chosen as they were coming into bloom, care being taken to select not only those that were growing vigorously but also small and stunted ones. Pollen was collected individually from the plants selected soon after the first flowers began to open, additional daily sampling being continued until the plants were nearly mature (April 26 to May 23). The duration of blooming period varied among the plants, the large plants usually having a longer season than the small ones. High winds which sometimes came up rather suddenly and scattered the pollen before all samplings of a given day were completed, are responsible for the occasional breaks in a series of observations.

In 1938 and 1939, similar tests were carried out but the pollen collections were made only during the height of the blooming period.

1/Sugar-beet seed, in commercial usage, refers to the nutlike fruits or fruit clusters that arise as the flowers mature. Commonly two or more flowers grow together at their bases and form a hard, irregular, dry glomerule or seed ball, the perianths hardening and drying down on the ovaries. The true seed is a small, shiny lentil-like structure with a curved embryo enclosing a perisperm. Development of the seed ball to normal size may proceed irrespective of fertilization. Seed balls low in vitality commonly show empty ovaries except for the brownish, dried-up integuments of the unfertilized ovules.

2/Unpublished data from tests conducted in cooperation with H. E. Brewbaker.

Viability tests were made by using artificial media, such as employed by the writer in earlier experiments 3/. It was found best to pour the Petri dishes just before use. Since the sugar concentration of the media was rather high (40%), the latter had to be handled while still hot in order to obtain a thin agar film. To prevent water condensation in the form of small droplets over the layer of agar, the dishes with the freshly poured agar were allowed to cool before the covers were applied. The prepared Petri dishes were taken to the field between 8:30 and 9:30 in the morning, depending upon temperature and wind conditions. Pollen samples were obtained by holding the open Petri dish beneath a branch of the seed bush and shaking the bush slightly. The exposed plates were kept at a temperature of approximately 30°C. There appears to be no well-defined temperature level for best germination. Pollen tubes develop almost as rapidly at summer room temperature as at the lower temperatures in the beet field during the blooming season. At temperatures above 30°C., there is always danger of the formation of water droplets from condensation on the concentrated sugar medium, with detrimental effects on the growing pollen tubes. The pollen was left to germinate until about 4:00 in the afternoon, when the plates were examined and the germination graded as follows: 0, no germination; 1, very poor germination; 2, poor germination; 3, fair germination; 4, good germination; 5, excellent germination.

The records for the germination tests, together with the climatological data for the sampling period, are summarized in table 1.

DISCUSSION

The daily pollen germination records for the entire group of plants and the seasonal, individual records deserve consideration. From the first-named approach, any correlations of pollen viability prevailing with climatic conditions should be revealed, as well as indicating the relative amount of fertile pollen available for open pollination of the flowers. The individual plant behavior should indicate both the amount and constancy of germination to be expected within the population, information of value in breeding and genetics investigations.

The daily germination record for 1937 shows that, with the exception of two days, there was no great variation, at least not important enough to affect materially the pollen supply for good seed setting. To be sure, the daily mean was almost always below the theoretical average, but this fact should have little practical significance because the amount of pollen produced is relatively large. The situation was somewhat different for May 13 and 18, for which the mean ratings were 0.56 and 0.11, respectively. If these ratings are accepted as typical for the field at large, the probability is that on these two days the pollen supply was not adequate. May 14 and 19, however, brought an ample supply of pollen; and since the stigma of the beet flower is believed to remain normally receptive for several days, the flowers that failed to pollinate on the days of poor pollen supply were pollinated on the succeeding day.

The mean daily germination record (table 1) for 1938 and especially for 1939 was much higher than for the preceding year, even if we allow for the fact that samples were taken mostly during the height of the blooming period.

3/Artschwager, E. and Starrett, R. C. The time factor in fertilization and embryo development in the sugar beet. Journ.Agr.Research 47:823-843. 1933.

The daily pollen supply was exceptionally good, and only a few cultures showed no germination.

A comparison of germination averages for individual selections in 1937 discloses an appreciable difference in performance. One plant gave an exceptionally low average of 0.94. Its seasonal record shows that on several days the pollen did not germinate at all; this would probably result in spotty seed setting under isolation. Under ordinary field conditions, failure on the part of a few individuals to produce viable pollen should not affect seed setting unless poor pollen production and low receptivity on the part of the stigma are associated phenomena. However, such a combination is probably rare, if found at all, since all the plants studied during the season of 1937 produced good seed. Relatively poor pollen was produced in 1937 by 8 out of 50 plants. The daily germination ratings for these were consistently low, although there was some viable pollen in all Petri-dish cultures, except on occasional days. On days when the performance of the high-and medium-rating individuals was above average, the poor pollen producers generally showed also a higher rating, indicating that the factors that influence pollen viability in general have a favorable effect on poor pollen producers. Five plants had a high-germination rating and one had a consistently high record, although its mean was slightly depressed because of the zero ratings for May 13 and 18.

The individual performance during 1938 and 1939 was much better than for the previous season and extremely low ratings were absent. Many plants showed a consistently high rating while a few were always low. It is evident that there is a range in capacity to produce viable pollen among individuals and that environmental conditions rather strongly influence the situation.

Studies of the plates showed that high-germination ratings commonly were associated with high-germination energy. With collections of this type, the pollen grains germinated almost immediately after being sown on the agar, and the pollen tubes were always very long. In certain of the plants selected, the pollen tubes frequently burst, a phenomenon that was found to be more pronounced on some days than on others. Bursting of emerging pollen tubes may be associated with some change in the osmotic concentration of the pollen grains for which the 40% sucrose agar employed in these test plates was no longer suitable. If pollen grains show the same differential reaction on the surface of the stigma, varieties in which this condition is pronounced must be grouped under poor or unreliable pollen producers unsuitable for inbreeding work.

Size of plant or vigor was apparently not associated with capacity for pollen production, since some small, stunted individuals produced pollen with as good a germination rating as tall, strong plants. On the other hand, pollen quality seemed to be a characteristic of the individual. This may be illustrated by contrasting two individuals of the 1937 series. These plants were adjacent in the field and both were unusually small. The mean germination rating of one was 2.88; for the other, 2.00.

The effect of irrigation on pollen viability is difficult to determine, for during the blooming season the fields are irrigated each week and the soil moisture is naturally not depleted. No consistent differences in daily germination ratings that might be attributed to irrigation effects were observed. From the data in table 1, it appears that for 1937 and 1938 high relative humidity of the air, within the limits shown for these tests, is not necessarily associated with poor pollen germination. Pollen viability and

morning humidity (8:00 a.m.) did not show significant correlation; pollen germination and evening humidity (8:00 p.m.) showed a small but significant positive correlation of 0.14.

No very definite correlations of pollen germination with environmental factors were found, nor could comparisons of behavior on selected days be used to indicate effects of specific climatic factors. For example, pollen germinations for May 13, 1937 were very poor (0.56); both temperature and relative humidity were average, but exceptionally strong winds prevailed. The weather on the preceding day was normal, with average wind movement. On May 17 and 18, 1937, the weather was also normal except for slightly elevated temperatures. The average pollen germination ratings for these two days were 2.63 and 0.11, respectively. The poor germinations on May 13 and 18 could not be assigned to any unusual weather conditions. In general, lower night temperatures, within the limits of the exposures given seemed to favor pollen germination, since pollen viability and night temperatures (minimum temperatures cf. table 1) show a correlation of 0.28, significant at 1 percent point.

The analysis of pollen germinations for 1937, 1938 and 1939 shows that daily fluctuations of the mean germination rating existed, as well as differences in individual performance. These three seasons were good seed years, the 1938 and 1939 crops being, in general, of better quality judging by average size of seed ball and smaller percentage of the crop rejected as screenings. The 1939 crop, although of fine quality, was light due to poor stand resulting from a heavy freeze early in November and again late in spring when development of seed stalks was well under way. During the blooming season the weather of these years was devoid of extremes. In 1937, the rainfall was less than normal and temperatures, on the whole, were favorable. Unusually high winds were limited to a few days. The weather in 1938 and 1939 just before the blooming season was favorable to the development of seed stalks. During blooming, untoward climatic conditions lasting any considerable period did not occur.

With the 1936 observations in mind, it seems that, although germination of sugar-beet pollen is subject to external influences, failure of pollination, which is to be attributed solely to poor pollen, is to be expected only if unusual conditions are continuous and prolonged. It is recognized that rain may affect pollen directly, causing it to burst, but under the conditions in New Mexico rainy periods are probably not of long enough duration to be a serious factor. From the 1937, 1938, and 1939 tests, it appears that, regardless of temporary fluctuations and poor performance of some individuals, there is always enough pollen in the air to assure pollination of opening flowers. The relatively long receptive period of the embryo sac, as demonstrated with emasculated flowers, would indicate that untoward effects on pollen would be remedied on succeeding days.

Unfavorable weather conditions may also produce ill effects on the female part of the flower. The egg cell is well protected and not very subject to injury by abnormal environmental conditions. The writer's experience in heat-treatment experiments in which, following differential heat exposures, the floral parts were examined cytologically showed that injuries to pollen mother-cells, the stigma, and integuments of the ovule near the micropyle occurred with high heat exposures 4/ had no apparent effect on the egg cell.

4/ Branches with flowers in all stages of development were immersed for five minutes in water at 43 C. and exposures for 15 minutes at 42° C. were used.

High winds associated with high temperatures were not shown to have detectable effects on pollen germination; on the other hand, such weather combinations could have ill effects on the stigmatic surface or more exposed parts of the pistil, bringing about such deterioration as would interfere with pollen germination, growth or penetration.

It probably will be found that the unusual climatic factors associated with low seed viability produce their ill effects on both pollen and pistil, the probabilities being that pistillate parts are frequently more decisively concerned than the pollen.

SUMMARY

Sugar-beet pollen germinates readily on an agar medium containing 40% sucrose and 1½% agar. Individual selections show great variation in seasonal performance, indicating that among beet plants there are good and poor pollen producers. Selections with a high germination rating usually have a high germination energy, giving rise to growing pollen tubes almost immediately after the pollen is sown on the culture medium. The daily germination record of all the individuals also shows variation but there is little correlation between environmental anomalies and germination behavior. Usually there is enough pollen available each day to effect fertilization of the opening flowers even if the germination average is below normal.

Poor pollen and poor seed setting may be associated phenomena if unfavorable weather which is known to reduce pollen viability, continues for several days; this holds true provided the receptivity period of the embryo sac is short, so that belated fertilization of flowers is unlikely. Often poor seed-setting is directly traceable to injury to the female part of the flower, especially the stigma which is sensitive to hot, windy weather. Good pollen germination throughout the season usually indicates a good seed crop, while consistently poor germination suggests the presence of some unknown environmental anomaly which prevents proper fertilization and seed setting through a harmful influence on the development of one or both essential parts of the flower, or of the young embryo in its initial stages of development.

Table 1. —Germination ratings and meteorological data by days, 1937-39.

Date	Number of Observations	Frequencies of Germination Ratings							Meteorological Data						
									Temperatures			Humidity			
		None 0	Very poor 1	Poor 2	Fair 3	Good 4	Very Good 5	Mean	Max.	Min.	Mean	8:00 AM	8:00 PM	Rain 1/	Wind total miles
1937															
April 26	10	-	1	7	2	-	-	2.1	82	41	61.5	31	16		120
27	10	-	1	6	2	1	-	2.3	79	42	60.5	12	12		297
28	5	-	1	-	2	2	-	3.0	72	42	57.0	36	25		232
29	12	-	3	1	4	3	1	2.58	72	38	55.0	22	21		188
30	28	1	6	11	8	2	-	2.14	72	36	54.0	34	22		142
May 1	23	-	4	5	9	4	1	2.69	76	32	54.0	33	20		96
2	-	-	-	-	-	-	-	-	83	41	62.0	36	25		133
3	29	-	1	7	15	6	-	2.89	77	45	61.0	48	33		262
4	30	1	4	6	11	7	1	2.73	77	53	65.0	50	34	†	270
5	29	1	2	7	10	6	3	2.93	79	57	68.0	42	32	†	257
6	39	2	11	9	10	6	1	2.23	81	50	65.5	75	29		184
7	38	1	17	9	4	6	1	2.00	84	45	64.5	62	25		93
8	39	3	3	6	9	14	4	3.00	89	44	66.5	43	21		98
9	40	3	13	14	5	5	-	1.90	82	51	66.5	46	39		183
10	49	1	9	11	12	15	1	2.69	82	49	65.5	49	21		126
11	50	-	3	18	11	15	3	2.94	85	38	61.6	30	16		140
12	50	-	2	13	22	13	-	2.92	89	43	66.0	45	17		122
13	50	39	1	5	3	2	-	.56	83	57	70.0	44	25		334
14	44	-	5	12	18	7	2	2.75	90	54	72.0	56	21		144
15	39	-	3	11	14	11	-	2.84	95	54	74.5	41	23		110
16	-	-	-	-	-	-	-	-	96	57	76.5	31	31		135
17	27	-	3	10	8	6	-	2.63	95	50	77.5	37	22		108
18	27	24	3	-	-	-	-	.11	93	63	78.0	37	33		151
19	25	-	-	6	11	8	-	3.08	90	55	72.5	55	27		128
20	11	-	-	2	9	-	-	2.82	90	51	70.5	41	19		103
21	21	-	-	3	5	10	3	3.62	90	46	68.0	41	17		94
22	10	-	-	1	5	4	-	3.30	86	51	68.5	31	24		329
23	11	-	-	2	6	3	-	3.10	82	65	73.5	74	46		228
Total	746	76	96	182	215	156	21								

1/ Too small for recording.

Table 1. (Con'td.)

Date		Number of Observations	Frequencies of Germination Ratings							Meteorological Data						
										Temperatures			Humidity			
			None 0	Very poor 1	Poor 2	Fair 3	Good 4	Very good 5	Mean	Max.	Min.	Mean	8:00 AM	8:00 PM	Rain 1/	Wind total miles
1938																
May	11	40	-	9	14	14	3	-	2.27	85	45	65.0	55	14		120
	12	40	1	5	11	17	3	3	2.62	86	42	64.0	61	20		110
	13	40	-	1	7	16	12	4	3.27	89	53	71.0	38	25		97
	14	40	-	-	8	14	10	8	3.45	93	50	71.5	32	21		191
	15	-	-	-	-	-	-	-	-	93	59	76.0	46	17		204
	16	40	-	2	6	16	12	4	3.25	87	62	74.5	27	21		150
	17	40	-	1	7	16	11	5	3.30	85	52	68.5	41	20		154
	18	40	-	1	15	12	9	3	2.95	79	62	70.5	42	68	+	157
	19	-	-	-	-	-	-	-	-	82	47	64.5	52	22		119
	20	38	-	-	6	13	16	3	3.42	89	44	66.5	39	20		120
	21	38	-	1	9	17	7	4	3.10	89	43	66.0	30	42	+	146
	22	-	-	-	-	-	-	-	-	82	53	67.5	38	18		205
	23	39	-	2	9	11	11	6	3.25	82	46	64.0	40	31		181
	24	43	-	-	4	17	13	9	3.63	86	63	74.5	42	21		193
	25	44	-	-	7	15	17	5	3.45	93	48	70.5	42	13		94
	26	-	-	-	-	-	-	-	-	93	55	74.0	34	17		109
	27	42	-	-	10	13	13	6	3.36	97	50	73.5	38	16		92
	28	44	-	1	11	15	14	3	3.16	94	53	73.5	27	18		135
	29	41	-	1	6	17	10	7	3.39	93	51	72.0	27	21		171
	30	42	-	-	14	21	7	-	2.83	92	45	68.5	42	17		139
	31	41	-	-	4	22	13	2	3.32	95	52	73.5	39	27		106
June	1	41	-	-	11	17	13	-	3.05	94	52	73.0	39	22		214
	2	38	-	2	8	19	5	4	3.03	97	65	81.0	41	21		350
	3	-	-	-	-	-	-	-	-	96	57	76.5	37	16		128
	4	-	-	-	-	-	-	-	-	92	62	77.0	44	54		153
	5	-	-	-	-	-	-	-	-	96	60	78.0	45	31		132
	6	24	-	2	2	14	5	1	3.04	98	65	81.5	41	23		147
Total		795	1	28	169	316	204	77								

1/ Too small for recording.

Table 1. (con'td)

Date		Number of Observations	Frequencies of Germination Ratings							Meteorological Data					
										Temperatures			Humidity		
			None 0	Very poor 1	Poor 2	Fair 3	Good 4	Very good 5	Mean	Max.	Min.	Mean	8:00 AM	8:00 PM	Rain 1/ Wind Total miles
1939															
May	8	9	-	-	4	4	1	-	2.66	85	51	68	27	12	110
	9	48	-	8	12	14	8	6	2.83	89	43	66	29	12	93
	10	48	2	13	11	8	4	10	2.60	90	44	67	32	12	102
	11	50	1	4	8	8	11	18	3.78	86	48	67	33	14	125
	12	50	1	7	7	11	13	11	3.22	85	45	65	25	14	44
	13	50	-	5	10	18	13	4	3.02	72	52	62	52	35	180
	14	-	-	-	-	-	-	-	-	80	47	64	63	27	170
	15	50	-	-	4	8	18	20	4.08	83	52	68	48	18	135
	16	50	1	4	13	15	5	12	3.10	83	43	63	30	18	181
	17	52	-	4	5	11	14	18	3.71	86	49	68	34	14	95
	18	51	-	4	4	13	18	12	3.59	91	46	69	35	11	45
	19	50	1	6	13	16	12	2	2.76	93	47	70	31	11	143
	20	-	-	-	-	-	-	-	-	93	43	68	38	13	100
	21	-	-	-	-	-	-	-	-	92	45	69	25	15	118
	22	-	-	-	-	-	-	-	-	92	45	69	21	26	128
	23	44	-	6	10	11	10	7	3.05	89	50	70	23	8	137
	24	36	-	6	8	9	9	4	2.92	83	47	65	30	14	175
	25	-	-	-	-	-	-	-	-	82	48	65	24	6	137
	26	38	-	3	2	7	14	12	3.79	86	51	69	22	12	112
	27	32	-	1	5	10	12	4	3.40	92	45	69	22	11	73
	28	-	-	-	-	-	-	-	-	93	48	71	31	20	248
	29	31	5	7	2	8	7	2	2.35	85	58	72	47	22	+ 174
	30	-	-	-	-	-	-	-	-	83	60	72	21	38	137
	31	31	3	8	8	7	2	3	2.19	89	62	76	56	20	101
June	1	-	-	-	-	-	-	-	-	90	53	72	38	14	93
	2	30	8	4	2	8	5	3	2.23	95	53	74	27	15	170
Total		750	22	90	128	186	176	148							

1/Too small for recording.

BREEDING METHODS WITH SUGAR BEETS; GREENHOUSE AND FIELD TECHNIQUE

C. W. Doxtator 1/

In order to develop varieties superior in performance to those now being used in sugar beet producing areas, the plant breeder must not only use breeding methods best suited to the crop, but he must also make use of practical methods which will achieve results in a minimum length of time. The purpose of this paper is to briefly outline the breeding program which has been developed during the past five years by the Beet Seed Department of the American Crystal Sugar Company, and to indicate some of the progress already made.

Methods of Breeding and Results

The adaptation of varieties to the extreme diversity of crop conditions 2/ found in American Crystal Sugar Company beet growing areas is a problem of first importance. Mass selection and mother line breeding methods are being used in all factory areas for the purpose of obtaining adapted varieties with the minimum of effort and expense. In 1937 at all factory areas, selections of roots from the better yielding varieties were made. In Table I is shown the 1939 yield data from two of these selections, in comparison with the parent varieties.

Table I.—Comparison of Yield of Selected Strains and Original Parent Variety. (1939 data). (Mass Selection Method)

Variety	Tons Beets	% Sucrose	Lbs. Sugar Per Acre	Test Area
No. 1	14.38	13.08	3859	East Grand
Original Parent	13.14	12.54	3327	Forks,
Difference	1.24	.54	532	Minnesota.
Sign. Diff.(19:1)	1.13	.75	426	
No. 2	14.62	13.43	3914	
Original Parent	12.28	13.04	3217	Chaska,
Difference	2.34	.39	697	Minnesota.
Sign. Diff.(19:1)	.96	.39	515	

Variety No. 1 was a selection for a short season area, and made from a foreign variety. Variety No. 2 was selected under leafspot conditions for a leafspot area, and was made from a home grown leafspot resistant variety. The data shown indicate a superior performance for the selections.

Mother line breeding has given equally promising results when used on varieties already improved by mass selection. In 1939 at Rocky Ford, Colorado, 45 mother progenies were tested in field trial with the parent variety. Of these 45 progenies 19 produced significantly higher yields than the improved parent variety. At the present time this method of breeding is being used to an increasing extent at all factory areas.

1/ Plant breeder, American Crystal Sugar Company.

2/ Beets are grown in peat and sedimentary soils; under irrigation and natural rainfall conditions; in altitudes ranging from sea level to 7600 ft.; in latitudes ranging 35° to 49°; and under coastal and continental climates.

An extensive amount of inbreeding is also under way at the present time. Self pollination as well as "brother-sister" sib pollination has been used to obtain pure lines. A sizeable number of lines of fourth and fifth generation of inbreeding have been obtained, and most of these lines possess marked uniformity of type. The most desirable are now being synthesized into experimental hybrid varieties for test purposes.

Greenhouse Technique

The use of greenhouses to supplement field breeding operations has been found to be extremely helpful in speeding up the work of variety improvement at Rocky Ford, Colorado. Being a biennial plant, the sugar beet normally takes most of a second summer season to complete its life cycle and produce seed. Consequently, the speed of variety improvement work with beets is half as fast as that which could be obtained from an annual flowering plant such as corn or sorghum. Since beet seed is normally planted in the spring season of each year there is a natural division into two breeding programs and the selected progenies from each program will flower and set seed in alternate years. If however, inbred progenies are planted in August in greenhouses, harvest of stecklinge can be made in December, thus giving adequate time for dormancy under normal cold conditions during the winter months. The stecklinge which are transplanted the following spring will produce seed in July in time for fall planting in greenhouses a second year. Similarly, inbred progenies planted in the field in the spring and producing roots in summer can be replanted in the greenhouse in late December and seed obtained from them in the following April in time for spring planting. Thus, greenhouse space can be used to transform the beet plant from a biennial, flowering in alternate years, to an annual, flowering in summer and winter seasons. This is of real value in speeding up genetic purification by inbreeding.

It is possible to further speed up the breeding work by planting greenhouse produced stecklinge back in the greenhouse in late February (after two months dormancy) and obtain seed for special test plantings in late May of the same year. Inbred lines can be indexed for bolting tendencies during the winter months. This work can be done to great advantage on greenhouse produced stecklinge. If desired, a large amount of hybridization work can be carried on during the winter months in the greenhouse making seed available for test plantings in the coming season.

In using the greenhouses for winter seed production it is necessary to use artificial light to obtain rapid bolting and seed setting. Artificial light has been used for this purpose at Rocky Ford since 1921 with satisfactory results. For summer use, lath shades are employed to reduce the intense heat and light in the greenhouses. Sprinklers placed on the roof of each greenhouse are also used to reduce temperatures to normal during the months of July and August.

Field Technique

Mass Seed Increase

In selecting beets in the field for mass seed increase, canes or lath stakes are used to mark beets for resistance to leafspot during the months of August and September. Continuous inspection of the marked plants is made and all beets showing susceptibility at later dates are discarded. Selection is made for root type at time of harvest; and for percent sucrose during winter

storage. In the spring, the selected beets of each variety are transplanted in space isolated groups for seed production. Seed obtained from these groups constitutes breeders stock of new selections.

Inbreeding

Since all roots selected for new breeders stocks are carried in pedigree record, inbred lines are begun from selected roots by placing one or more kraft bags on branches of the plant prior to flowering. Seed obtained from these plants, as well as seed from inbred lines produced in field and greenhouses are planted in three inch pots in the greenhouses in April. Normally, only the small seed lots are thus planted. In May, these plants are removed to the field, and at that time inbreds having large seed lots are planted directly in the field. During the summer this nursery is subjected to periodic night sprinkling from an overhead sprinkler, for the purpose of inducing a leafspot epidemic. Usually not more than ten percent of the inbred progenies planted are found to be satisfactory in resistance to the disease. Roots of these selected lines are either used for greenhouse planting, or stored and replanted in the field for further breeding work.

Roots of inbreds obtained from field selections, as well as stecklinge produced from inbred seed in the greenhouses are transplanted to the field each spring, where all are subjected to further inbreeding. Some of the more uniform lines are crossed (using bags) for the production of natural single crosses. In the event that certain of these hybrid combinations appear to be of promise, the seed supplies of the parent inbreds are increased for possible large scale production of hybrid varieties.

A STUDY OF SUGAR BEET HYBRIDS

H. W. Dahlberg 1/

Since the year 1934, many studies have been made of various wild types of Beta Maritima by our organization, with repeated selections of the most promising types. In view of the fact that these wild types show such great variability, description of them is left to showing a series of lantern slides. (Most of the slides shown were used in connection with a later discussion of the crosses and back crosses between wild types and certain Great Western breeding material).

Considerable optimism is required to persevere in a breeding program which includes many lines of hybrid families. The first generation hybrids are nearly always disappointing in both size and type of roots, these being small, scrawny and very much sprangled. While sugar content and purity are fair, both are generally definitely lower than for commercial beets. The following are typical for 1st generation hybrids between wild Beta Maritima and Great Western families.

Weight of root	-	6 to 10 ozs.
Polarization	-	11 to 14 percent
Purity	-	77 to 84 percent

1/ Research Manager, Research Department, Great Western Sugar Company, Denver, Colorado.

At the first annual meeting of this Society held in Salt Lake City in 1938, information was presented by the author 2/ on a particular hybrid and the first back cross of the hybrid, which seemed to indicate a type which was rather superior to those usually obtained. The hybrid seed was produced in 1935, by crossing roots of three North Sea wilds with two roots of a Great Western variety. The seed was grown in the authors garden, and the two lots of seed gathered from the Great Western mother plants were called Dahlberg #3 and Dahlberg #4 respectively.

These two lots of seed were grown for observation at Fort Morgan in 1936, the plants showing unmistakable hybrid character, strong vigor, and good resistance to leafspot. A selection was made from these F_1 roots and 29 of them were backcrossed with a corresponding number of sugar beet roots (G.W. family 12028) in the greenhouse during the winter 1936-37, giving rise to breeding group E. 2136. Seed from this first backcross was planted on a large scale for observation in 1937 and continued to show very good performance.

In 1938, a new backcross was made between Dahlberg #4 and G.W. 3642 resulting in breeding group E. 538. In 1939, this backcross was tested in comparison with the Great Western standard variety, with gratifying results as shown in the following comparison:

	Yield	% Sugar	Total Sugar	Tons Per A.	Polarization
Great Western Standard	100.00	100.00	100.00	14.93	17.16
3462x Dahlberg #4	103.62	96.27	99.75	15.47	16.52
Dahlberg #4x3462	104.82	95.92	100.55	15.65	16.46

Since these figures represent mixed seed from 14 families in each case, it is evident that there would be some individual families which show a definitely better performance than the average. Since the Great Western standard variety used in these comparisons has demonstrated itself as a yield type of high performance under a widespread set of conditions, it is gratifying to have a number of lines containing wild blood which promise to exceed the standard in tonnage. These lines are also desirable in that they have very good leafspot resistance, and under leafspot conditions should show an even better performance. The root type of these lines is entirely satisfactory from the commercial standpoint.

In addition to the backcross described above, our organization now has several hundred families which are the result of the second backcross between hybrids and Great Western families. These are being rapidly tested for performance, as we believe that many of them will show promise as commercial varieties. These hybrid families are characterized by large vigorous tops, a rather shiny leaf, and well shaped long roots.

Up to the present time we have found the North Sea type of Beta Maritima to be the best starting point for introducing wild blood into our lines. In the course of the next two years we will have more tests on hybrids resulting from other wild types originating on the Atlantic coasts of Europe, and it is possible that some of these will equal our present North Sea hybrids. We are well satisfied regarding the advantages which may come by introducing additional genes into the present types of sugar beets which probably have resulted from a narrow base of selection.

2/ Dahlberg, H. W. SOME OBSERVATIONS ON WILD BEETS (BETA MARITIMA). PROCEEDINGS: AMERICAN SOCIETY OF SUGAR BEET TECHNOLOGISTS. Page 76. 1938.

PERFORMANCE OF TONNAGE, INTERMEDIATE AND SUGAR TYPES IN SOME INTERMOUNTAIN DISTRICTS

C. E. Cormany and F. F. Lynes
Holly Sugar Corporation

No one variety or type of corn, wheat, oats or potatoes is entirely suitable or adapted to all climatic conditions. Results of tests from many sources show that the same may be true for sugar beets and it appears that there is no such thing as a universal variety.

The desire that each factory district have a high yielding, sweet beet of good quality for maximum production of sugar, has been the goal of all sugar companies for years. Tests for adaptability have been made from time to time at various places in the United States for the last thirty years or so. The most extensive type study on record is that conducted by the Division of Sugar Plants. 1/ This circular reports results with nine brands of imported sugar beet seed in 44 tests in a four year series at thirteen locations. One of the conclusions of this circular is that "the best agricultural practice cannot overcome the use of a type of beet unsuited to that area."

Imported sugar beet seed has been divided into three general types according to the producers as: (1) Tonnage, or yield type, where total yield of roots per acre is stressed; (2) Sugar type, where a high sugar content per root is obtained; and, (3) Intermediate type, which combines as far as possible, both yield and sugar type characteristics to a certain degree.

In order to determine the type or types of sugar beets best suited to each of our northern factory districts the three types were placed in our tests, seed being chosen from the most reliable European sources.

The study reported in this paper is based on data obtained in detailed variety tests during 1937, 1938 and 1939 in Holly Sugar Corporation factory districts in Montana and Wyoming. The area covered ranges geographically over 7° in latitude, or about 500 miles, extending from Sidney, Montana, which is very close to the Canadian border, to Torrington, Wyoming, near the Colorado State line. The elevations vary from about 1900 feet above sea level at Sidney to 3800 feet at Sheridan and 4000 feet at Worland and Torrington. The soils on which the tests were conducted were of average productivity for the respective districts. The average season between planting the seed and harvesting the crop was as follows: Sidney, Montana, 146 days; Hardin, Montana, 145 days; Sheridan, Wyoming, 146 days; Worland, Wyoming, 162 days; and Torrington, Wyoming, 171 days. Although the season in days is longer at Torrington, the actual sunlight at Sidney makes up for a portion of this difference, because the days are much longer in the northern area and actual growth and development of the plant is correspondingly greater per day.

Summary data covering these tests for three years is presented herewith:

1/ Skuderna, A. W. et. al. 1938. EVALUATION OF SUGAR BEET TYPES IN CERTAIN SUGAR BEET GROWING DISTRICTS IN THE UNITED STATES. U. S. D. A. Cir.476, 28 pp. illus.

TYPE PERFORMANCE IN CERTAIN MONTANA AND WYOMING LOCATIONS

Type	Sidney	Rank	Hardin	Rank	Sheridan	Rank	Worland	Rank	Torrington	Rank
PERCENT SUCROSE										
Sugar	16.31	3	16.95	1	16.66	1*	16.95	1	14.33	2
Intermediate	16.57	1	16.75	2	16.63	2*	16.85	2	14.43	1
Tonnage	16.34	2	16.55	3	16.29	3	16.50	3	13.67	3
Diff. for Sig. Odds 19:1	.43		.70		.25		.77		1.08	
TONS PER ACRE										
Sugar	18.808	2	16.189	3	13.075	2	15.722	3	15.746	3
Intermediate	17.802	3	18.618	1*	12.844	3	16.575	1	16.411	1
Tonnage	19.804	1*	17.401	2	14.096	1*	16.514	2	16.127	2
Diff. for Sig. Odds 19:1	1.298		2.134		.764		1.021		1.680	
GROSS SUGAR PER ACRE (Pounds)										
Sugar	6140	2	5612	3	4372	2	5334	3	4518	2
Intermediate	5930	3	6379	1	4299	3	5552	2	4740	1
Tonnage	6504	1*	5910	2	4617	1*	5611	1	4403	3
Diff. for Sig. Odds 19:1	435		779		250		503		606	

*Significantly superior.

A study of these data shows that the seed types performed as advertised for sucrose content, the sugar and intermediate types being sweetest.

The best average returns in tons per acre were obtained from the tonnage and the intermediate types. In production of roots variation for locality became manifest, the heavy yielding types forging ahead at Sidney and Sheridan and the intermediate types being leaders at the other places.

In gross sugar per acre, which is a criterion for selection, the tonnage type averaged highest, the intermediate next and sugar type third, with types indicated for locations as follows: Sidney, tonnage; Hardin, intermediate; Sheridan, tonnage; Worland, tonnage and intermediate; and, Torrington, intermediate.

In general tonnage types were indicated for the more northern areas and intermediate types for the southern portion of the locations studied.

PERFORMANCE OF DIRECT INCREASES OF PEDIGREED AND COMMERCIAL LOTS OF SUGAR BEETS

By H. E. Brewbaker 1/

Reversion in type, or "running out", has been taught by biologists and emphasized by seedsmen and breeders until it is almost axiomatic to the average person. In self-pollinated crops such as wheat, oats, barley, and beans there is no logical reason to suppose that any material change will take place within a variety which originated as a pure line so long as ordinary care is exercised to prevent seed mixtures.

The problem is not so clear with naturally cross-pollinated crops such as corn and sugar beets, for the ordinary commercial variety consists of a heterogeneous mixture of types. So diverse is this mixture, in fact, that when self-fertilized to produce inbred lines it is difficult to find any two such lines which bear much resemblance.

With corn it might conceivably be supposed that the same genetic factors that contribute to high yield of seed would tend to a gradual increase of the higher producing types, but even the most refined ear-to-row methods failed to show improvement in experiments conducted by Hayes and Alexander (2)2/. Moreover, mutations probably occur so seldom and are usually abnormal recessives, thus tending to be self-eliminating, that it is hardly conceivable they can contribute to any evident "running out" (3).

With sugar beets the possibility of change in yield through mass increase would seem to be less than in corn for there is very little if any correlation between yield of roots or sugar and production of seed (1). This does not apply, however, to the character of bolting or seed production, it having been sufficiently demonstrated in recent experience that incomplete bolting in the Southwest may result in an increase of the quickly bolting types. This has become evident in some increase in bolters in commercial beet fields planted to seed produced in Arizona. While this has rarely resulted in over 1% of bolters in Northern Colorado, that in itself being of little importance except from the esthetic standpoint, it has served as a precaution against continued increases of commercial to commercial in seed-producing areas where this type of natural selection may take place.

The results which I am to report were obtained during the 1939 season at Longmont, Colorado. Both the parental variety and the mass increase were included in a variety test with 9 replications of 49 varieties. The arrangement was a two dimensional quasi-factorial scheme with three groups of sets. Plots were 4 rows by 30 feet at harvest, approximately half of the beets being taken at random for sugar determinations and all beets for yield of roots. The yields and sugar were calculated in per cent of Great Western commercial (GW18) used as the Standard. The results are given as loss or gain in per cent of the Standard, for the increase as compared with the original, as follows:

1/ Agronomist, Great Western Sugar Company.
2/ Figures in parenthesis refer to "Literature Cited".

Varieties		Loss or gain, % of Standard		
Original	Increase	Yield	Per cent Sugar	Total Sugar
GW1011	GW1044(b	-2.85	-0.27	-3.16
GW1011	GW3 (c	+0.80	-1.63	-0.87
GW1020	GW38 (d	-3.25	-2.24	-5.47
GW1009				
GW1011	GW34 (b	-4.73(a	-0.33(a	-4.42(a
GW25	GW33 (d	-1.48	-2.58	-4.10
GW31	GW32 (e	-5.31	-2.11	-7.30
GW20	GW23 (f	+3.25	+1.90	+5.09
GW21	GW27 (f	+4.83	+0.47	+4.43
Diff. for Sig.(single comparison)		-6.33	-4.21	-8.44
Mean difference		-1.09	-1.32	-1.98
t test, P = between		0.4 & 0.5 Not sig.	0.1 & 0.2 Not sig.	0.2 & 0.3 Not sig.

a) Average for original weighed for relative proportion in seed mixture used.
b) Produced in Colorado by steckling method.
c) Produced in New Mexico by overwintering method.
d) Produced in Arizona by overwintering method.
e) Produced in Texas by overwintering method.
f) Produced in Colorado by overwintering method.

The mean loss in per cent of Standard was 1.09 for yield of roots, 1.32 for per cent sugar, and 1.98 for total sugar. Comparisons of the increase with the original were made using Student's method, the t test indicating differences less than expected on the basis of odds of 19:1, hence, are generally considered not significant. This is to be expected since the individual comparisons are not consistent, there being some losses and a few gains. It is of further interest that for no single comparison was significance established. It can only be suggestive that the gains of appreciable magnitude for yield and per cent sugar, viz., for GW23 and 27 from GW20 and 21, respectively, were seed increases made by the overwintering method in Colorado. All other seed increases were made either in the Southwest by the overwintering method or in Colorado by the steckling method. It is also of some interest that losses of yield were accompanied by losses in per cent sugar in all cases, and gains in yield by gains in per cent sugar in two out of three cases.

Further tests will be necessary before any definite conclusions can be established. Since this problem is one which every sugar beet breeder or seed producer cannot easily ignore, it is hoped that sufficient evidence will be obtained before the next general meeting of this Society to establish the facts with respect to the loss or gain which may be expected with mass increases of sugar beet varieties.

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COMPARISON OF SOME ADVANCED GENERATIONS OF A HYBRID STRAIN OF SUGAR BEET WITH THE ORIGINAL THIRD GENERATION SELECTION1/

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Introduction

Sugar-beet breeding investigations in United States have reached the point where inbred lines are becoming available for use in hybrid combinations. There has been considerable exploration of the possibilities of combining existing inbreds which in themselves may be more or less satisfactory for commercial use, in order to obtain superior varieties for general introduction. Large mass increases from seed mixtures of more promising inbreds have been made, notably in the recent Bureau introductions, U. S. 217 and U. S. 200 X 215. By pooling the seed of inbred strains and then carrying this mixture forward to seed production, an attempt has been made to utilize first-generation hybrid vigor, the experience being that a considerable amount of hybridization occurs in the seed field. Obviously, the progenies consist of selfs of the parental strain and the hybrid. As yet, certified hybrids have not been produced in quantity for direct use by sugar-beet growers, nor have the F_1 hybrids been carried to advanced generations for commercial use. The following data dealing with Hybrid Strain 520 and its selected and non-selected advanced generations are presented as having bearing on the question of what may be expected from advanced generations of sugar-beet hybrids.

Origin of the Hybrid Strain 520

In August, 1930, the American Crystal Sugar Company planted a field on their West Ranch farm at Rocky Ford, Colo., with seed of their sugar-type variety, Flat Foliage, for the production of stecklings to be siloed and replanted in the spring of 1931 for seed production. A few rows on one edge of this field were left in the ground in the fall and a small proportion of the beets in these rows was alive the next spring, having survived the winter. Forty of these stecklings showing the least frost injury were planted in the spring of 1931 with 10 red garden beets which had been kept in a pit over winter by a local gardener. These red beets are believed to have been of the Detroit Dark Red variety. The red beets were slow in starting but did produce a scanty growth of seed stalks, blooming rather late in the season. The following year, 1932, the open-pollinated seed saved from the 40 sugar-beet plants was planted and showed that there had been about 5 percent of intercrossing of the sugar beets with the red garden beets.

A seed crop was produced in 1933 from the sugar beet X red garden beet hybrids, crossing taking place *inter se*. In 1934, a considerable second-generation progeny was grown. No genetic analysis of this crop was attempted. However, the presence of red, white, and a few yellow roots, the great range in root shape from garden-beet to sugar-beet type, and a considerable range in sucrose percentages are sufficient evidences that segregation for different characters had occurred. Many of the white roots were of such large size and

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1/ Agronomic investigations at Fort Collins, Colo. are conducted in cooperation with the Colorado Agricultural Experiment Station. The early work with Hybrid Strain 520 was conducted at Rocky Ford, Colo. in cooperation with the American Crystal Sugar Company. (Cooperative assistance of the Great Western Sugar Company, and the Holly Sugar Corporation in conduct of field tests with strain 520 is hereby acknowledged.)

fair to good sucrose percentage that it was decided to select for the production of a white-rooted third generation. Since the roots with white epidermis and flesh color lack the dominant factor Y, elimination of red or yellow fleshed beets in future progenies is thus accomplished.
The basis of selection in size and sucrose percentage was roughly that of gross sugar per root. No roots of pronounced garden beet shape were retained, but most of the selected beets were shorter and thicker than the conventional sugar-beet type and the crowns of many of the beets retained were unusually small. One hundred and twenty pounds of cleaned seed were produced in 1935 from a group planting of about 560 of these selected roots. This seed had the planting number 520 and this selected third-generation of the hybrid has been known since as Hybrid Strain 520.

Hybrid Strain 520 has been extensively tested in the beet-growing areas of Colorado (with the exception of the western slope) and in some other states on the eastern slope of the Rocky Mountains in 1936, 1937, 1938, and 1939. In general, it has equalled or surpassed the better commercial varieties in acre-yield of roots in these tests. Sucrose percentages have almost invariably been below those of the majority of commercial varieties with which comparisons were made. However, the sucrose percentage of Hybrid Strain 520 has not been so low as to make the variety definitely unsatisfactory for sugar manufacture. Because of the high yield of roots, the acre-yield of sugar has, in general, been approximately equal to that of the better commercial varieties. Examples are the 1937-1939 averages at Fort Morgan, Colo., in a high-yield, low-sucrose-percentage area; and the 1938 test at Sheridan, Wyo., where relatively high percentages of sucrose are expected. Summarized data from these tests are given in Table 1.

The showing of Hybrid Strain 520 in 1936 and in succeeding trials appeared to justify further work with this hybrid. By the spring of 1939, several different advanced generations produced by direct increases, as well as by selection, were available for testing in comparison with the original stock. Those of most interest for the purposes of this report are as follows:

Table 1.—Results from comparative tests of Hybrid Strain 520 and a commercial variety at Fort Morgan, Colo. (3-year average), and at Sheridan, Wyo., in 1938.

Place	Variety	Acre-yield of Gross Sugar	Acre-yield of Roots	Sucrose
		pounds	tons	percent
Fort Morgan, Colo.	Hybrid Strain 520	5,593	21.57	12.93
do.	Commercial	5,590	19.68	14.10
Sheridan, Wyo.	Hybrid Strain 520	5,687	17.36	16.20
do.	Commercial	5,548	15.39	18.05

Planting designation	Current Breeding No.	Generation	Description
1	520	F_3	Foundation stock arising from Sugar Beet X Red Garden Beet
2	304	F_4	Selection from 520 on basis of saccharimeter test
3	301	F_4	Direct increase without selection from 520
4	302	F_5	Direct increase without selection from 304
5	300	F_4	Selection essentially the same as 304
6	250B	F_4	Selection from 520, for improved sucrose percentage; size of root ignored.
7	80186	F_4	Selection from 520 made in Wyoming (pink bud color)
8	80187	F_4	Selection from 520 made in Wyoming (green bud color)
9	250A	F_1	Hybrid of 520 X commercial
10	-	-	An American variety used as check
11	-	-	A European brand used as check

The strains listed above were used in trials in 1939 as follows: (1) all were included in a test on the College Farm at Fort Collins, Colo.; (2) five were used in strip plantings made in a farmer's field near Fort Morgan, Colo.; (3) six were used in a replicated test at Rocky Ford, Colo.; (4) six were used in a replicated test at Sheridan, Wyo.; and (5) one was tested at Sydney, Mont. An American variety used as a check was common to tests 1, 2, 3, and 4. A European brand used as a check was common to tests 4 and 5. Limited seed supply of certain of the strains and other considerations prevented uniform testing of all the above generations at each of the locations. The data as obtained at these five locations have been brought together in Table 2 for acre-yields of roots and gross sugar and for sucrose percentages.

Table 2.—Results obtained in 1939 at various locations with Hybrid Strain 520 and certain advanced generations. (Results given as averages.)

Planting designation	Variety	(1) Fort Collins Colo.	(2) Fort Morgan Colo.	(3) Rocky Ford Colo.	(4) Sheridan Wyo.	(5) Sydney Mont.	Averages Locations 1-3	Averages Locations 1-4
		tons	tons	tons	tons	tons	tons	tons
		Calculated Acre-Yields of Roots						
1	520	14.45	23.12	12.86	11.88	—	16.81	15.88
2	304	14.64	22.75	12.05	12.10	21.39	16.48	15.38
3	301	12.61	22.08	12.96	—	—	15.88	—
4	302	13.60	21.31	12.56	10.83	—	15.82	14.58
5	300	13.98	22.55	11.87	—	—	16.13	—
6	250B	13.47	—	—	—	—	—	—
7	80186	13.86	—	—	13.61	—	—	—
8	80187	13.34	—	—	12.52	—	—	—
9	250A	15.32	—	12.44	13.06	—	—	—
10	Check	13.74	20.54	11.05	10.19	—	15.11	13.88
11	Check	—	—	—	10.52	19.18	—	—
Difference required for significance 19:1		1.87	1.27	2.56	1.49	2.58		

Table 2 (con'td.)

Planting designation	Variety	(1) Fort Collins Colo.	(2) Fort Morgan Colo.	(3) Rocky Ford Colo.	(4) Sheridan Wyo.	(5) Sydney Mont.	Averages Locations 1-3	Averages Locations 1-4
		Sucrose Percentages						
		percent	percent	percent	percent	percent	percent	percent
1	520	15.96	15.20	16.73	14.60	—	15.96	15.62
2	304	16.27	15.41	17.06	15.15	15.54	16.28	15.97
3	301	15.61	14.82	16.59	—	—	15.67	—
4	302	15.85	15.07	17.00	14.68	—	15.97	15.65
5	300	16.05	15.44	16.98	—	—	16.16	—
6	250B	16.64	—	—	—	—	—	—
7	80186	15.29	—	—	14.71	—	—	—
8	80187	15.28	—	—	14.41	—	—	—
9	250A	16.39	—	17.23	15.19	—	—	—
10	Check	16.95	16.21	18.14	15.59	—	17.10	16.72
11	Check	—	—	—	16.24	17.17	—	—
Difference required for significance 19:1		.57	.49	.38	.54	.65		
		Calculated Acre-Yield of Gross Sugar						
		pounds	pounds	pounds	pounds	pounds	pounds	pounds
1	520	4,614	6,999	4,280	3,461	—	5,298	4,838
2	304	4,792	7,011	4,054	3,672	6,642	5,286	4,882
3	301	3,960	6,525	4,293	—	—	4,926	—
4	302	4,308	6,424	4,237	3,156	—	4,990	4,531
5	300	4,490	6,957	4,002	—	—	5,150	—
6	250B	4,490	—	—	—	—	—	—
7	80186	4,256	—	—	4,018	—	—	—
8	80187	4,084	—	—	3,612	—	—	—
9	250A	5,037	—	4,244	3,965	—	—	—
10	Check	4,663	6,742	3,974	3,169	—	5,126	4,637
11	Check	—	—	—	3,431	6,617	—	—
Difference required for significance 19:1		693	690	831	517	911		

Stands or soil variability, or both, were unfavorable in the case of the tests at Fort Collins, and Rocky Ford, Colo., and at Sheridan, Wyo., but it is believed that, in general, the reliability of the tests was not seriously impaired. However, in some cases, rather large differences do not reach the level of statistical significance.

It was hoped that these tests would give information on the relative progress to be expected from continued selection, chiefly for improved quality, following the original selection of desirable segregates from a hybrid.

The performance of 304, 300, 250B, 80186, and 80187 in relation to each other and in comparison with 520 should bear on this point. Since 520 was high in yield of roots and somewhat low in sucrose percentage, the purpose of further selection was to retain the high tonnage and increase the sucrose percentage of this hybrid, if possible. Seed of 304 was available for testing in 1938 and it, with 520, was included in plantings at Fort Collins, Colo., Fort Morgan, Colo., and Sheridan, Wyo. Data from these tests are summarized in Table 3.

Table 3.—Summary of performance of 304 and of 520 at three locations, Fort Collins and Fort Morgan, Colo., and Sheridan, Wyo., in 1938.

Variety	Acre-yield of gross sugar			Acre-yield of roots			Sucrose percentage		
	Fort Collins	Fort Morgan	Sheridan	Fort Collins	Fort Morgan	Sheri-dan	Fort Collins	Fort Morgan	Sheri-dan
	pounds	pounds	pounds	tons	tons	tons	percent	percent	percent
520	4,837	4,388	5,687	17.97	18.37	17.36	13.46	11.97	16.30
304	5,040	4,433	5,904	18.21	17.99	17.60	13.84	12.32	16.83
Commercial ck.	4,934	4,840	5,548	16.98	17.98	15.39	14.64	13.46	18.05
Difference required for significance 19:1	392	245	516	1.26	.86	1.41	.37	.34	.64

It appears from the 1938 tests that reselection has not sacrificed tonnage and that sucrose percentage has probably been increased significantly. When the data from the various 1939 tests are considered, it is found that 304 again exceeds 520 in sucrose percentage in every case, the differences reaching the level of statistical significance in some of the cases. Also, tonnage in the case of 304 has been quite satisfactorily retained. On the basis of the Fort Collins test, the selection for higher sucrose, 250B, shows a substantial increase in sucrose percentage. However, this increase in quality has been accompanied by a reduction of approximately one ton in acre-yield of roots. While this difference does not reach twice the standard error of a difference, it is too large to be entirely ignored as evidence of a trend. In these tests, 300 does not appear to be quite the equal of the first reselection, 304. However, the differences are not significant and the trend indicates that in this selection quality has been slightly raised without serious sacrifice of yielding capacity. The performance of the Wyoming selections 80186 and 80187 at Fort Collins, Colo., and at Sheridan, Wyo., in comparison with 520 and 304 is of interest in that the possibility of regional adaptation is involved since these selections were made from Wyoming-grown roots of 520. At Fort Collins, the Wyoming selections appear to be definitely lower in sucrose percentage than the original selection and both of the Colorado F_4's, 304 and 300. Yield of roots is also lower, but the differences are probably not significant on the basis of this test. 80186 exceeded 80187 in acre-yield of roots, sucrose percentage, and acre-yield of gross sugar at Fort Collins, Colo., but the differences do not appear to be significant. At Sheridan, Wyo., the Wyoming selections exceed 520 and 304 in root yield. In the case of 80186, these differences reach the level of statistical significance. The Wyoming selections do not differ significantly in sucrose percentage from 520. On the basis of this test, the selection of Wyoming-grown roots has resulted in a possibly significant increase in root yield without a loss in sucrose percentage. While the evidence is far from conclusive, it is possible that regional adaptation is indicated in this case. At Fort Collins and Rocky Ford, Colo., and at Sheridan, Wyo., 250A, the 520 X Commercial hybrid gave a high yield of roots with a sucrose percentage that is probably significantly higher than the sucrose percentage of 520 in all cases. These tests indicate that crossing of such a strain as 520 with a good commercial variety promises as quick or quicker improvement than continued selection.

A question which arises in beet breeding work may also be considered, namely, can the general trend of performance of a hybrid sugar beet best be maintained when non-selected increases are made for production of seed in com-

mercial quantities. The relative performance of the unselected advanced generations, 301 and 302, should be indicative of the performance of commercial increases of the Hybrid Strain 520. While the groups of stecklings which produced these seed lots consisted of only a few hundred roots, they are probably comparable to a crop of seed produced on a commercial scale by direct increase of seed since there was no selection of the roots used for these groups. In general, the differences in acre-yields of roots and acre-yields of gross sugar shown by the various strains of 520, whether selected or unselected, did not in these tests reach the level of statistical significance. This is true of the unselected strains, 301 and 302, whether they are compared with 520, the selected strains, or with each other. In the Rocky Ford test, the extreme difference is less than 300 pounds of sugar per acre. In the other three tests, in which one or both of the unselected strains were included, there appears to be a definite trend toward slightly lower yields of roots in comparison with the parent strains, 520 and 304. The trend in sucrose percentages is the same; 301 is slightly lower than 520, and 302 slightly lower than 304. These differences both in yield and quality are small and, on the basis of these tests, the unselected increases are not definitely poorer than the parent strains. It is believed that the basis of selection of both 520 and 304 was such as to retain a high degree of heterozygosity for the factors influencing both yield and quality. If this is true, it is logical to expect that the normal segregation in the unselected increase of either would result in certain individuals with small size or low sucrose percentage. If this has occurred, there might be a lowering of the general level of performance. This does not necessarily follow, however, since in the case of sucrose percentage, at least, there should also be segregation in the direction of higher sugars. It is worthy of note that 302 appears to have retained a portion of the improvement in sucrose percentage gained in the selection of 304. These tests, while not proving the case, at least can be interpreted as not disproving the practicability of increasing a hybrid such as 520 without selection after the third and fourth generations.

Summary and Conclusions

A high-yielding hybrid sugar beet has been produced from the cross of sugar beets from a variety classifiable as of sugar type and red garden beets.

An increase in quality, as measured by sucrose percentage, was obtained by reselection from the third generation. This increase in quality was not accompanied by a material decrease in tonnage.

When the selected fourth generation was advanced to the fifth generation without selection, part of the increase in sucrose percentage was retained. The unselected fourth and fifth generations, on the basis of these tests, were probably not significantly lower in sucrose percentage and root yield than the parent third and fourth generations, respectively.

The slightly higher tonnage and increased sucrose percentage shown by the cross of 520 roots with a good commercial variety in comparison with 520 shows that this method of utilizing a promising hybrid combination should not be overlooked.

It appears from these tests that it is possible by careful reselection to increase the quality of a hybrid strain without materially reducing the yield of roots.

Since in these tests definite retrogression in yielding capacity and quality of a hybrid strain was not found as advanced generations beyond F_3 were made, it may be possible to make direct increases from similar hybrid stocks without material loss occurring in yielding capacity as measured in acre-yield of gross sugar.

PROGRESS IN GENETICS — NEW METHODS IN PLANT BREEDING

G. H. Siegumfeldt 1/ 2/

Ever since the rediscovery of Mendels law, there has been a reciprocal action between Genetics and Plant Breeding and without doubt to mutual benefit to both.

Plant breeding problems which should be of interest to the Genetic Section of this Society are:

1. Breeding For Resistance
2. Heterosis
3. Polyploidy

Considering the recently developed science of Applied Heredity, the foregoing are old problems, which in the light of newer advances made in their respective fields assume importance for future breeding methods.

Breeding for Resistance

Plant diseases affect agriculture adversely. This subject can be divided into two parts:

1. Diseases primarily of interest to the plant pathologist;

2. Diseases which cause large losses to agriculture. Notable examples of this latter class are rusts, leafspots, rots, smuts, and the like.

"Many of these diseases can be effectively controlled in various manner by the farmer, by such means as seed treatment, specific rotations, spraying, etc. Most of these methods are costly, however, and may not always be possible to accomplish. It appears reasonable therefore, that the most effective way to approach the problem is through disease resistant and disease tolerant varieties of crops. However even in this case the problems are beset with difficulties." At this point, the history of wheat breeding in this country and Canada was considered, pointing out how some varieties were apparently resistant for years to a certain physiologic form of wheat rust only to become susceptible later to new forms of the disease.

Breeding of beets resistant to Cercospora beticola was next considered. It was brought out that while we have sugar beet strains resistant to this disease, their behavior may be quite different when tested in countries other than those where they were developed. For example, Austrian varieties of Cercospora resistant beets were found susceptible in Canada, and Canadian varieties were found susceptible in Spain.

"To test this point the following study was made. Cercospora spores were gathered from five different countries. Six resistant strains of sugar beets each outstanding in the country where tested were used to test the infectivity of different strains of Cercospora spores. The seed was planted in sterilized soil in greenhouses where conditioned air, moisture and soil con-

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1/ Danish Sugar Beet Seed Company, Copenhagen, Denmark.
2/ Condensed by A. W. Skuderna.

ditions were kept favorable for the development of the disease. The study showed that four different strains of Cercospora were actually secured, the fifth being identical in infection to strain one as shown in Table I.

Table I. Infectivity of Cercospora Spores on Six Resistant Varieties of Sugar Beets.

Sugar Beet Varieties		A	B	C	D	E	F
Cercospora	1	+	X	+	X	+	X
Strains	2	X	X	X	+	+	+
	3	+	+	+	+	+	+
	4	X	X	+	X	X	X
	5	+	X	+	X	+	X

"We do all expect that sugar beet resistance is due to the presence or lack of genetic factors, but the experiment indicates in several cases convincingly, that a single genetic factor is effective only on one or a few contagious races of Cercospora. It must therefore be the task of the sugar beet breeder to introduce his breeding material resistant factors to as many contagious races of Cercospora as possible." (Dr. Siegumfeldt then added that we must be prepared for some disappointments when present varieties are tested under varying conditions of leafspot intensity. He concluded with the statement that fortunately in such cases the farmer has recourse to sprays, treatments, etc.).

Heterosis

The speaker then discussed heterosis in beets, pointing out that it took a varying number of generations of inbreeding and self pollination to insure purity of type. By crossing such inbred progenies it is possible to hybrid vigor markedly. As a rule about 80-85 percent true hybrids are obtained from such crosses, which for practical purposes he concluded was satisfactory. He added, that this type of beet breeding had its drawbacks, it being necessary to have material of diverse origin, a large number of pure lines and inbred lines to make the crosses, making possible thereby new combinations and eventual improvement of the beet by this controlled method of breeding. He stated, "In combining heterosis breeding with polyploidy, it should be possible to make great improvement, and this method I think will be of great importance for future sugar beet breeding."

Polyploidy

"This is the oldest method of breeding agricultural crops, such as wheat, oats and barley which must have originated from wild species. Increased vitality and vigor distinguish these plants with an increased number of chromosomes in their cells. It is only in the past ten years that the utilization of polyploidy in plant breeding has been recognized, and only in the past few years have reliable practical methods been available". Under this head come three methods:

1. The Callus Method
2. The Shock Method
3. The Colchicine Method

Callus Method

"This method is dependent upon the possibility that in vegetative parts of the plant close to the cambium layer, cells occur in which cells or cell groups have a double number of chromosomes in their nucleus. By making an incision close to such points, and continuously removing new buds from the incised wound, it is possible to force new growth of buds containing tetraploid cells from the callus on the wound surface".

The Shock Method

"The principle of this method is to disturb the first division of the embryo after fertilization takes place, so that no wall between the two nuclei is formed. Under controlled temperature and humidity conditions the length of the period between fertilization and this first division is ascertained." At the end of this period, the embryo is exposed to a shock (such as a rise in temperature, high electric current, Xray, etc.) for a period of 2 to 4 minutes. "By properly timing the shock, it is possible to prevent cell division, with the result that the two nuclei merge together immediately, or after the next division, thus forming a tetraploid nucleus, cells and embryo. By a cold shock, it is possible to release diploid pollen or eggcells. Tetraploid sugar beet plants have been obtained by using this method."

The Colchicine Method

"This method is very effective and simple to use either on seed or on the bud of the plant to be treated. It consists of one or several treatments a few hours at a time with an aqueous solution of Colchicine, which affects the nucleus dividing mechanism in the metaphase stage in such a way that only one tetraploid instead of two diploid nuclei are formed. As plant tissue is restrained in growth by this treatment, it is necessary to cut back surplus buds so as to secure the best possible growth condition for the wanted buds".

"The Colchicine Method was published in 1937, but had been used on many different plants with good results, and especially so when combined with the callus method. The practical significance of this method is in vitality, heavier growth, just what is apparently needed for heavier yields. Experience however has not shown this to be the case. In the case of the potato, the number of tubers and yield per hill decreased despite increase in size of tubers. With cabbage, the results have been very good. As a rule, tetraploid seed has a very low germination. With cereals, the tetraploid grain produce larger kernels and smaller yield than diploid seed".

"With sugar beet seed it has not been possible thus far to produce germinating tetraploid seed from tetraploid beets. Further, tetraploid plants as a rule are much more susceptible to diseases than diploid plants. However, this method must still be regarded as being in the experimental stage and should prove to be a valuable factor in the breeding program. Tetraploid plants tend to produce offspring with intensely disintegrating characters. Such plants can be crossed with other tetraploids, giving rise to new combinations which would be impossible to duplicate with diploids alone."